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A Breeding Landbird Inventory of Yukon-Charley Rivers National Preserve, Alaska, June 1999 and 2000.

Final Report

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EXECUTIVE SUMMARY

In 1998, Yukon-Charley Rivers National Preserve received funding from the National Park Service Inventory and Monitoring Program to inventory avian species in the 2.5 million acre Preserve. The goals for the subsequent inventory were to 1) design and implement an avian inventory plan in the Preserve with methodology suitable for large parks and preserves that have minimal access and 2) develop a long-term monitoring protocol for birds in the Preserve.

We employed a stratified random sampling design that randomly selected sampling blocks (township and range blocks, approximately 10 km x 10 km) in proportion to availability of ecological units. During the June breeding seasons in 1999 and 2000, we quantified vegetation and used the variable circular plot technique with unlimited distance estimation to survey birds at 1415 points.

We detected 12,266 birds of 85 species at count stations over the 2 years (Chapter 1). An additional 30 species were detected while traveling between points. We detected 86% of the 134 bird species thought to breed in the Preserve. Three species know to occur but not expected to breed in the Preserve—Long-billed Dowitcher, Least Flycatcher, and Solitary Vireo—were detected during the inventory.

Passerines were well represented in the inventory with the exception of American Dipper, Northern Shrike, and swallows (detected but in low numbers). Taxonomic groups that were not well inventoried using our survey methods included: waterbirds (i.e. loons, grebes, and waterfowl), raptors (i.e. hawks, falcons, and owls), gulls and terns, and woodpeckers. We detected 9 of the 13 shorebird species expected to breed in the Preserve (in low numbers) at sample points; 2 additional shorebird species were identified between sample points.

We calculated density estimates for 36 of the most common bird species (Chapter 2); these 36 species represented 98% of all individuals detected during the inventory. Species densities were calculated for the Preserve, dominant landforms, and each detailed ecological unit. Precision of density estimates increased when counts were stratified by detailed ecological units. Due to species specific detection rates, species counted most often were not always those with the highest density.

Based on density estimates, the most abundant species in the Preserve were Yellow-rumped Warbler, Dark-eyed Junco, White-winged Crossbill, White-crowned Sparrow, and Boreal Chickadee. Sparrows had the highest density of any group detected, followed by the warbler, thrush and flycatcher groups, respectively.

Univariate analysis of habitat data was performed to examine individual species selection of breeding sites in relation to tree canopy cover, percent coniferous trees, and percent shrub cover (Chapter 3).

We examined species richness, abundance distribution, and diversity within and between ecological units (Chapter 4). Subsections with complex vegetation mosaics (those containing ecotonal boundaries, varied topography, diverse water resources, or high incidence of wildfire) had high avian species diversity. Avian species diversity was

relatively low in ecological units containing large tracts of lowland Black Spruce vegetation.

The success of our inventory was due to several factors. First, stratification of blocks by ecological subsection and points by detailed ecological units helped us sample all representative habitat types in the Preserve. Second, our seasonal and daily sampling frames were appropriately chosen to target the periods when most species were present and actively singing, calling, or displaying. Third, our use of longer point count periods (8 minutes) allowed us to detect species that would have otherwise been missed with shorter counts (5 minutes). Finally, our meticulous preparation of logistics and training of personnel enabled us to efficiently survey a large Preserve with minimal access in a short period of time (3 weeks).

This inventory effort has provided the necessary data to set up a long-term monitoring program for the Preserve, however, protocols for accomplishing this are not included in this document.

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INTRODUCTION

The mission statement of the National Park Service (NPS) asserts that “the National Park Service preserves unimpaired the natural and cultural resources of the National Park System for the enjoyment, education, and inspiration of this and future generations”. Currently, NPS is unable to attain its mission in many parks due to a significant lack of scientific information about the nature and condition of their biological resources. In addition to an insufficient baseline of information about the biological resources in its parks, NPS generally lacks credible information about the current status of those resources and how they are changing over time in response to the myriad threats and issues affecting them.

To address this general deficiency of information about park biological resources, Congress passed the National Parks Omnibus Management Act in 1998, which mandated the establishment of an inventory and monitoring program to establish baseline and long-term monitoring information for National Park System resources. This was initiated through increased funding to the Service-wide Inventory and Monitoring (I&M) Program of the National Park Service. The basic goal for the biological component of the I&M program is to provide park managers with comprehensive, scientifically based information about the status of selected biological resources occurring within park boundaries. This information will be used to help make management decisions, conduct and direct scientific research, and educate the public. The inventories are also intended to lay the groundwork necessary for park managers to develop effective monitoring programs and management strategies for biological resources within the parks.

In 1998, the I&M program solicited proposals from selected parks to conduct inventories documenting the occurrence, distribution, and relative abundance of bird species. These inventories were to: 1) document the occurrence of at least 90% of the species of birds estimated to exist in the park via field investigations; 2) describe the distribution and relative abundance of federally-listed threatened, endangered, and exotic bird species occurring within park boundaries; and 3) provide information necessary to design a monitoring strategy for birds within the parks. In addition, the selected parks were asked to insure that their inventories incorporate the major park ecosystem components, processes, and stressors that influence the distribution and life histories of birds in the parks.

Yukon-Charley Rivers National Preserve was one of the NPS units that received I&M funding to conduct a bird inventory. The complex geology, climatic conditions, natural fire regime and discontinuous permafrost in this 2.5 million acre Preserve has produced a diverse landscape and thus provides habitat for a vast array of bird species. The presence of 163 species (many of them Neotropical migrants) has been documented in the Preserve (Walker 1999). Based on literature searches, observations, and professional knowledge, 134 of these species are expected to breed in the Preserve. The Yukon River serves as a natural corridor that funnels birds migrating to and from Alaska during spring and fall migration periods. This natural corridor is also responsible for the occurrence in the Preserve of many vagrant species from more southern and eastern temperate regions.

Our goals for the Yukon-Charley Rivers National Preserve Bird Inventory Project were to: 1) design and conduct an avian inventory for the Preserve with methodologies suitable for large parks and preserves that have minimal access and 2) develop a long-term monitoring protocol for birds in the Preserve. To achieve these goals, we developed the following specific objectives:

1. Collect and summarize all existing information on the distribution and abundance of birds in Yukon-Charley Rivers National Preserve;
2. Obtain and develop geographic data layers needed to characterize avian habitats (vegetation, hydrology, fire history, and ecological units);
3. Determine associations between bird abundance by species and habitat characteristics for at least 90% of the bird species estimated to breed in the Preserve and extrapolate this information to obtain park-wide abundance and distribution estimates;
4. Examine distribution and relative abundance for wintering birds;
5. Inventory owl species in each of the ecological subsections; and
6. Design a bird monitoring program for detecting changes in population size of selected bird species.

Based on these goals and objectives, we developed a sampling design to inventory breeding birds on a landscape scale and provide a sampling framework upon which to base a monitoring program. With the data collected from that inventory, we were able to obtain relative abundance and distribution information for 85 avian species (Chapter 1); produce density estimates and distribution maps based on density for 36 species (Chapter 2 and Appendix V); evaluate structural habitat characteristics for several species (Chapter 3), and examine species richness and diversity (Chapter 4). Information on wintering birds and owls in the Preserve (Objectives 5 and 6 above) is presented in a separate report.

Fieldwork for this project was initiated in March 1999 with owl and wintering bird surveys (Swanson and Nigro 2000) which were continued in March 2000 and 2001. Spring breeding bird surveys were completed in June of 1999 (Swanson and Nigro 1999) and 2000. Data analysis and final products were completed during 2003.

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Funding for this project was provided through the National Park Service Inventory and Monitoring Program and enabled us to greatly improve our understanding of birds in Yukon-Charley Rivers National Preserve.

STUDY AREA

Yukon-Charley Rivers National Preserve is a 2.5 million acre National Park Service unit located in eastern interior Alaska, just south of the Arctic Circle, and bordering Yukon Territory, Canada (Fig. 1). The Preserve was established in 1980 by the Alaska National Interest Lands Conservation Act [Title II, Sec. (10)] to maintain the environmental integrity of the Charley River watershed and the populations of fish and wildlife within its borders.

Elevation in the Preserve rises from 220 m at the Yukon River to 2000 m in the mountains to the south. The semi-arid continental climate in the Preserve area results in low annual precipitation ranging from a mean of 30.2 cm in the eastern portion of the Preserve to 20.9 cm in the western portion of the Preserve [National Weather Service data for Circle, AK (1957-1997) and Eagle, AK, (1949-1997)]. Mean daily temperatures range between 15.6°C in July and -25.0°C in January.

The Preserve lies within the subarctic boreal forest zone. The complex geology, climatic conditions, natural fire regime and discontinuous permafrost have produced a diverse mosaic of vegetation successional stages and taiga and tundra communities. Forest and woodland communities of black spruce (*Picea mariana*) dominate poorly drained sites. Coniferous stands of white spruce (*P. glauca*) and deciduous communities of quaking aspen (*Populus tremuloides*), paper birch (*P*. papyrifera) and balsam poplar (*P. basamifera*) characterize forests and woodlands on well-drained soils and south-facing slopes. Willow (*Salix* spp.), alder (*Alnus* spp.), and birch (*Betula* spp.) are the most common shrub species. Wetlands (bogs, marshes, and lake/open water areas) are common in the floodplains of the Yukon River. Alpine tundra communities predominate at elevations above 700 m.

INVENTORY METHODS

Sampling Design

We used a stratified random sampling design to select sampling sites within the 2.5 million acre Yukon-Charley Rivers National Preserve. Stratification was based on ecological subsections (Cleland et al. 1997, D. Swanson 1999; Fig. 2) that were delineated at a scale of 1:250,000 through qualitative interpretations of high-altitude color-infrared aerial photographs and available geologic and landcover data for the area (Brabb and Churkin 1969, Foster 1976, Dover and Miyaoka 1988, Ducks Unlimited 1998). Some ecological subsections were further delineated into detailed ecological units (Table 1). These units were not fine enough in scale to qualify as landtype associations (Cleland et al. 1997) but were readily delineated from color-infrared aerial photographs. Ecological subsections not further delineated into detailed ecological units have the same name reference for both the ecological subsection and the detailed ecological unit levels (Table 1). Fourteen ecological subsections and 29 detailed ecological units were classified for the Preserve (Fig. 2, Table 1).

Sampling units for the inventory were 9.66 km X 9.66 km township blocks created by overlaying the ecological unit map with a township and range grid (Fig. 3). This grid created 139 blocks that contained some portion of the Preserve. Only those blocks with at least 20% of their area contained within the Preserve boundaries were eligible for selection (126 blocks). We then assigned each block an ecological subsection designator, based on which ecological subsection occurred at the center of the block.

We determined that 20 blocks could be surveyed during each year given the short sampling timeframe (June 5-28), the number of personnel working on the project, and logistical constraints of surveying birds in a remote area. We then randomly selected 40 blocks (32% of the blocks available) in proportion to the area of the Preserve that each ecological section occupied (Table 1). For example, the Upper Charley Mountain Tundra Ecological Subsection (MT) comprises 24% of the Preserve, so 24% (10 blocks) of the 40 blocks randomly chosen for sampling were blocks designated as MT. An additional block from each ecological subsection was randomly chosen each year as an alternate in case the selected block could not be accessed by helicopter or the presence of wildfire, snow cover, or flooding rivers precluded sampling.

Prior to fieldwork, we mapped out 3 transects of 12 sampling points in each selected block. Blocks with <50% of their area contained within the Preserve were sampled with only 2 transect routes of 12 points each. Transects radiated from a campsite and sampling points along these transects were allocated in proportion to the area of the detailed ecological units found within the block. Campsites were selected using 1:63,360 topographic maps and aerial photos to locate safe helicopter landing sites with reasonable access to the areas to be sampled. The distance between points along each transect and points between adjacent transects was ≥ 400 m in open habitats and ≥ 200 m in treed habitats. We did not sample areas that were inaccessible due to steep slopes, unfordable rivers, snow depth, or recent burns with standing dead trees. Transect lines were generally orientated across major landscape gradients (i.e., up mountain slopes or perpendicular to the river on flood plains); however, transect lines often changed headings or had significant gaps between points in order to sample detailed ecological units in proportion to their availability (Fig. 4). Transects were modified in the field when the selected campsite was inaccessible by helicopter, bears were encountered, or snow or high water levels made the original transects unfeasible.

Field Methods

Each year, four 2-person field crews and one swing person were trained extensively in identifying birds by sight and sound, estimating distances to birds, measuring habitats and cataloging point locations. Three weeks were devoted to training to assure that all field technicians were proficient at data collection and to minimize observer effects on data collection. The swing person was used to substitute for injured or ill observers and to assist with project logistics.

Sampling Technique

We used variable circular plots (VCP; Reynolds et al. 1980, Ralph et al. 1995) with unlimited distance estimation to survey birds at sample points along transects. We targeted a minimum of 12 sampling points per transect, but as many points as possible were surveyed between 0230 h and 1000 h. The number of points per transect varied from 7 to 15, with fewer points sampled when weather or injuries caused delays in starting or early termination, or when rugged terrain required extended periods of travel between points.

At each sample point, we recorded distances to all birds seen and heard during an 8-minute count period (recorded as 2 intervals, 0-5 min. and 5-8 min.). Distances were recorded in 10-meter intervals out to 100 meters, in 25-meter intervals from 100 to 150 m, and as >150 m for distances beyond 150 m. Additionally, when traveling between points on a transect, we recorded all bird species not yet observed at the previous sampling points. Waterbirds, shorebirds, and raptors were inventoried opportunistically along transects to help us compile a more complete list of species for the Preserve.

We used a shotgun microphone attached to handheld tape recorder to record bird songs that we could not identify in the field, represented unusual dialects, or were from rare species that required verification. These recordings were audio-processed and archived digitally on Compact Disks.

Habitat data within a 50-meter radius around each sampling point was collected and included: elevation; slope; aspect; distance to water; type of disturbance (landslide, fire, etc); major tree species, height and percent cover; major shrub species, height and percent cover; major herb species and percent cover, and percent cover of moss and lichen species and ground litter. We also recorded the detailed ecological unit (D. Swanson 1999) and landcover type (Ducks Unlimited, Inc. 1998) at each sample point. Representative photos of landcover types and detailed ecological units were taken during the inventory to document the different vegetation communities and landscapes in the study area.

Field crews used Global Positioning System Units (GPS) to navigate between points and back to camp. However, more accurate Precision Lightweight GPS Receivers (PLGRs) were used to obtain the exact location of each sampling point. Sample point locations were recorded and saved in the field and later downloaded into a Geographic Information System (GIS).

Sampling Schedule

Field work began on 8 June 1999 and 5 June 2000, which is a few days earlier than the recommended 10 June start date for conducting off-road breeding bird surveys in Alaska (Handel 1999). These start dates were chosen so that 3 weeks of sampling could be completed before 30 June (the end of the recommended survey period for Alaska; Handel 1999). After this date many species stop or greatly decrease singing. Each field crew was responsible for surveying 5 blocks each year. Four days were spent in each block, with a different transect being surveyed each of the first 3 days and a move (by helicopter) to the next block occurring on the fourth day. In 1999, one crew moved between blocks by boat, but the length of time needed to move and manage the boat, in addition to the small number of blocks that could be accessed, negated this as a viable means of transportation between blocks.

Surveys began between 0200 and 0300 h and were completed by 1000 h. This daily sampling frame was based on peak passerine detectability determined during a 24-hour monitoring project conducted in the Preserve in 1998 (S. Swanson 1999). Birds were not surveyed when excessive noise from wind or rain diminished their detectability. During each survey, one observer surveyed birds while the other observer collected the associated habitat data. The crew switched data collection responsibilities throughout the season to control for observer bias.

In 2000, we examined seasonal changes in numbers of birds detected by repeatedly surveying 8 points on a low elevation (<800 m) route over two 3-day periods (June 15-17 and 24-26). Bird sampling techniques were the same as those described above (variable circular plots with unlimited distance estimation). Data from these routes were not incorporated into other inventory analyses and were used only to look at seasonal changes in the number of birds detected at that site.

CHAPTER 1. INVENTORY

One of the primary goals for this project was to design and implement an avian inventory for Yukon-Charley Rivers National Preserve with methodology suitable for large parks that have minimal access by road. In addition, we attempted to document the occurrence of at least 90% of the bird species estimated to breed in the Preserve and obtain the information necessary to develop a general monitoring strategy for the Preserve. This chapter discusses the inventory design we developed to accomplish these goals and objectives and the results of its implementation.

INTRODUCTION

Conducting a large-scale bird inventory minimally involves setting specific goals and objectives, gathering existing bird and habitat information, selecting methodologies to meet the objectives, determining a sampling strategy, preparing for and implementing the field surveys, and analyzing and reporting the inventory findings. Selecting the appropriate survey methodology is critical to inventory success. Selection of survey methods involves consideration of terrain, means of accessing areas for sampling, physical constraints of surveyors, and sampling timeframe (daily and seasonal), in addition to inventory objectives.

Methods frequently used for estimating bird abundance and density include spot- or territorial-mapping, area search, line transect, point count, and variable circular plot techniques (Buckland et al. 1993, Ralph et al. 1993, Lancia et al. 1994). Comparisons of the general survey characteristics, variables measured, and bird groups sampled for these survey techniques were made by Verner (1985), Butcher et al. (1992), Ralph et al. (1993) and Gibbons et al. (1996). We chose to use variable circular plot methodology for this inventory effort after taking into account our desired sampling scale, the ruggedness of the Preserve's terrain, cost per data point (including access costs), and our desire to estimate density with confidence intervals for comparison to future monitoring efforts. The vegetation structure in the Preserve is multi-layered and complex (with the exception of alpine areas) and the terrain is rugged. The difficulty of navigating and physically moving through this type of vegetation and terrain can severely impede one's ability to detect birds. In this type of terrain, point transects are probably the most efficient for surveying birds since a stationary observer can more effectively detect and estimate distances to birds (Dawson 1981).

Rough terrain also indicated the potential for extensive travel time between point count locations along each transect. The length of time spent surveying birds at each point requires balancing the need for acquiring a complete survey of the birds in the count area against maximizing the number of daily sampling points and hence the statistical power of the survey (Barker et al. 1993, Ralph et al. 1995). Dawson (1981), Barker et al. (1993), and Ralph et al. (1995) all recommend that the time spent at each point should increase as travel time between points increases. Ralph et al. (1995) further recommends that on surveys where travel time between points is >15 minutes, point count duration should be >5 minutes in length. Dettmers et al. (1999) examined bird-habitat relationships using logistic regression models and different point count lengths and they recommended using point count durations of 5 or 10 minutes for developing these models as well as for monitoring population trends. Based on this information, we decided to use a count duration of 8-minutes.

Using variable circular plot techniques also met our desire to estimate density with confidence intervals for individual species for comparison to future monitoring efforts. Incorporating distance estimation can increase the value of information collected from point count surveys by allowing the calculation of unbiased estimates of density (Buckland et al. 1993). Furthermore, these estimates of density can be controlled for variability in detection due to observer effectiveness or other measurable environmental factors (Buckland et al. 1993).

A variety of sampling designs are available for use in wildlife surveys and experimental research (Ratti and Garton 1994). In order to make Preserve-wide inferences about bird abundance and density, species distribution, and species/habitat relationships, we used a stratified random sampling design that selected sampling blocks in proportion to the availability of ecological units that characterized the Preserve (D. Swanson 1999). Stratified sampling is more efficient than strictly random sampling when land units (or strata) with different characteristics can be delineated (Ratti and Garton 1994) and subsequently used to reduce sampling variance and therefore estimate a parameter of interest with much greater precision (Greenwood 1996).

Determination of seasonal and daily sampling timeframes is a critical component of a sampling strategy. A breeding survey should be timed to maximize detections (either visual or auditory) of all breeding birds in an area (Skirvin 1981). Surveys conducted too early in the breeding season will be biased toward detecting year-round residents (Skirvin 1981), while surveys continued too late into the season will largely miss species that may have stopped or greatly reduced their singing levels. We timed our surveys to cover the seasonal period when birds were established on territories (i.e., birds were not transient or still in migratory status) and actively singing/calling.

Singing and/or calling is integral to detecting breeding birds and 91% of the bird detections in this inventory (n = 12,266 total detections) were auditory. Persistence and frequency of song throughout the breeding season depends largely on the song's function (Best 1981), some of which include territory advertisement, attraction of mates, and locational calls to other conspecifics. If the song is primarily used for territory advertisement, singing may be more consistent throughout the breeding season though there is often a gradual seasonal decline. In species where song evolved primarily for mate attraction, singing often decreases dramatically after pair formation. Singing is also affected by breeding behavior, nesting chronology, activity levels, habitat, and weather (Best 1981; Carbyn 1971). These variables can significantly influence the number of auditory detections of birds during a survey and therefore must be considered when selecting seasonal and daily sampling time frames that will maximize bird detections.

High rates of bird activity are typically found in the early morning hours immediately after sunrise during the breeding season (Holmes and Dirks 1978, Robbins 1981, Blake 1992, Smith and Twedt 1999). Sunrise in the Preserve during the breeding season is not clearly defined since there is nearly continuous daylight in the arctic at that time. However, Armstrong (1954) found that even in the arctic, the general level of bird activity was affected by light intensity and sun elevation, and bird activity corresponded closely with morning light intensity. To determine a daily sampling period, we conducted a 24-

hour bird detection pilot study in the Preserve prior to conducting the inventory (S. Swanson 1999). The peak detection period in the pilot study occurred between 0200 and 1130 h. Daily sampling was conducted 0200-1000 h in 1999 and we further restricted it to 0230-0930 h in 2000 due to physical constraints imposed by traveling in rough terrain.

ANALYTICAL METHODS

Means and standard errors were calculated for the number of birds detected per point (birds/point) and the number of species detected per point (species/point). Means are presented ± one standard error (SE) and P-values (P) ≤ 0.05 are considered statistically significant. Analysis of variance (Zar 1999) was used to assess differences in the mean number of birds/point between years, and the Levene Statistic (Zar 1999) was used to assess differences in the variance around these means between years. Simple regression (r^2; Zar 1999) was used to examine associations between birds/point (and species/point) and time of day and date. Simple regression with Bonferroni Corrections (α=0.025; Scheiner and Gurevitch 1993) was used to evaluate correlations between birds/point (and species/point) and date at high and low elevations.

RESULTS

During the 2-year inventory, we surveyed a total of 40 township/range blocks (Fig. 5), resulting in 12,266 bird detections (6,002 birds in 1999 and 6,264 in 2000; Appendix I) at 1,415 sample points (688 points in 1999 and 727 in 2000; Fig. 6). The sampled blocks accounted for 32% of the blocks available for selection (n = 126 available blocks) and were well distributed across the Preserve (Fig. 5).

Of the 134 avian species expected to breed in the Preserve, a total of 115 species (86% of the expected breeding species) were detected during the inventory. We detected 85 bird species (63% of the expected breeding species) during point counts and an additional 30 species between survey points, in camp, or during rest periods (Appendix I; Table 2). Three species know to occur but not expected to breed in the Preserve—Long-billed Dowitcher, Least Flycatcher, and Solitary Vireo—were detected during the inventory. Taxonomic groups that were not well inventoried using our survey methods included: waterbirds (i.e. loons, grebes, and waterfowl), raptors (i.e. hawks, falcons, and owls), gulls and terns, and woodpeckers (Appendix I). We detected 9 of the 13 shorebird species expected to breed in the Preserve (in low numbers) at sample points; 2 additional shorebird species were identified between sample points. Passerines were well represented with the exception of American Dipper, Northern Shrike, and swallows (detected but in low numbers).

The most commonly detected species were Dark-eyed Junco, White-crowned Sparrow, Yellow-rumped Warbler, Swainson’s Thrush, Varied Thrush, Common Redpoll, and White-winged Crossbill (Table 3). All of these species (except White-winged Crossbill) plus the American Robin were detected on more than 25% of the points sampled (Table 4). Spruce Grouse, Northern Shrike, Northern Shoveler, Ring-necked Duck, and Common Merganser were encountered on more than six of the sampling blocks, however, none of these species were detected during the point counts (Table 2).

We detected a mean of 8.7 ± 0.14 SE birds/point (range 0-78 birds/point, mode of 8 birds/point). Most high counts included flocks of Common Redpolls (ranging from 5-28 birds per flock) and White-winged Crossbills (ranging from 5-70 birds per flock), therefore the distribution of birds/point was slightly skewed (Fig. 7). There was no significant difference in mean number of birds per point between years (Analysis of Variance; $F = 0.145$, df = 1413, $P = 0.703$). Also, the variance around the means were also not significantly different between years (Levene Statistic = 1.482; $P = 0.224$), thus data from both years were combined for all analyses.

Sampling Distribution by Ecological Units

We sampled nearly all ecological units (both subsections and detailed ecological units) in proportion to their availability (Fig. 8a and 8b). Ecological units with terrain and habitats that were easy to walk through were sampled in greater proportion than their availability since time spent traveling between points was reduced and more points could therefore be sampled during the daily sampling period. For example, the barren domes and gentle vegetated ridges units of the Upper Charley Mountain Tundra Subsection (MT2 and MT3) and the Charley Foothills Subsection (CF) were all sampled slightly more than their availability because they consisted of either open terrain or treed habitats with a sparse understory. Conversely, travel in the Yukon River Valley Units (YV) was often difficult because of dense understory layers and well-developed wet tussock tundra fields.

Other ecological units were under represented due to fires, weather, or small total area. The Ogilvie Foothills (OF) and Yukon River Valley—Tatonduk Valley (YV7) subsections were sampled less than their availability due to wildfires in 1999 and difficulty of access. Rain reduced sampling in the Thanksgiving Loess Plain (TL) in 1999, resulting in overall reduced sampling for the unit. Two detailed ecological units, comprising only 0.6% of the Preserve, were not sampled during the inventory: Upper Charley Valleys—Upper Charley plain (UC4) and Yukon River Valley—Tatonduk Valley (YV7). Both units were narrow and linear and were not captured by our sampling design. The Upper Charley Valleys—Upper Charley plain detailed ecological unit (UC4) was inventoried using point counts in 2001 to assess species presence/absence (Appendix II), but results were not included in any analysis in this report.

Time of Day and Bird Detection

Greatest numbers of birds per point tended to be detected between 0300 and 0700 h (Table 5). Peak detection time was between 0430 and 0459 h when 10.0 ± 0.60 SE birds/point were detected. Although detection rates appeared to decline slightly after the 0630 h, the decline was not correlated with time of day ($r^2 = 0.064$, $P = 0.31$).

Seasonal Changes in Bird Detection

We found no correlation between the total number of birds detected per point and date ($r^2 = 0.039$, $P = 0.35$), but the number of species detected per point declined as the breeding season progressed ($r^2 = 0.314$, $P = 0.01$). At high elevations (> 800 m, $n = 675$ points), the number of birds detected per point declined with date ($r^2 = 0.338$, $P = 0.01$) as did the number of species detected per point ($r^2 = 0.260$, $P = 0.02$). We found no correlation at low elevations (≤800 m, $n = 740$ points) between date and the number of birds detected per point (r^2 = 0.039, P = 0.35) or between date and the number of species detected per point (r^2 = 0.066, P = 0.25).

In 2000, we repeated a survey route at a low elevation (≤800 m) six times between 15 and 26 June. As with the results above, we found no evidence for a correlation between the number of birds detected and date (r^2 = 0.017, P = 0.81) or between the number of species detected and date (r^2 = 0.054, P = 0.66) on this repeated route. Seventeen species from this repeated route were examined for correlation between the number of birds detected and date (Table 6). Though most species exhibited little or no evidence of correlation with date, the number of Orange-crowned Warbler and Varied Thrush detections decreased over time on the repeated route (r^2 = 0.769, P = 0.02 and r^2 = 0.698, P = 0.04, respectively) and the number of White-crowned Sparrow detections increased over time (r^2 = 0.665, P = 0.01).

Ecological Units and Bird Detection

Bird detection within ecological subsections ranged from 12.9 ± 0.59 SE birds/point (n = 54 points) in the Three Fingers Subalpine Basin to 4.6 ± 1.4 SE birds/point (n = 5 points) in the Snowy Domes unit (Table 7). The mean number of birds/point by species was calculated for each ecological subsection (Table 8). Thirty-eight species were found in only one ecological subsection. Most waterfowl species were found in the flood plain of the Yukon River Valley Subsection. Northern Wheatear, Gray-crowned Rosy Finch, Lapland Longspur, and Surfbird were only found in the Upper Charley Mountain Tundra Subsection and Western Wood-Pewee were only detected in the Ogilvie Foothills Subsection. Other species such as the American Robin, Orange-crowned Warbler, Fox Sparrow and Common Redpoll were widely distributed among ecological subsections (Table 8).

Of the detailed ecological units, the Ogilvie Foothills—Bluffs had the highest mean number of detections with 11.5 ± 1.5 SE birds/point (n = 2 points) and the Upper Charley Mountain Tundra—high and rugged unit was lowest with 2.2 ± 0.54 SE (n = 13 points) birds/point (Table 7). For each species, the mean number of birds/point was calculated for each detailed ecological subsection (Table 9 and 10) to obtain more specific information on where individual species occurred on the Preserve. For instance, within the detailed ecological units of the Upper Charley Mountain Tundra subsection (MT), Surfbirds were most abundant on the gentle vegetated ridges (MT3), Lapland Longspurs and Gray-crowned Rosy Finches on the barren domes (MT2), and Northern Wheatears on the high and rugged (MT1; Table 10).

Point Count Length and Bird Detection

We detected 80% of all birds (n = 12,266) and 89% of the 85 species identified on the inventory during the first 5 minutes of the 8-minute count period. Species detected only during the 5-8 minute period included: Pacific Loon, Lesser Scaup, Ruffed Grouse, Northern Hawk Owl, Short-eared Owl, Golden Eagle, Peregrine Falcon, Black-backed Woodpecker, and Pine Siskin. Also, >50% of all detections for Green-winged Teal, Black-capped Chickadee, Say's Phoebe, and Gray-crowned Rosy Finch occurred during the first five minutes of the count interval.

Travel times between points averaged 22 minutes in 1999 and 23 minutes in 2000 (overall mean was 22.7 minutes travel between points); these means were all >15 minutes, the travel time after which Dawson (1981), Barker et al. (1993), and Ralph et al. (1995) suggested required a point count duration of >5 minute.

DISCUSSION

With our inventory design, we were able to document 86% of the 134 species thought to occur in the 2.5 million acre Preserve during the breeding season (Appendix I), despite the fact that several bird taxonomic groups (e.g. waterbirds, raptors, gulls and terns, and woodpeckers) were not well inventoried using our survey methods. We virtually met the Inventory and Monitoring Program's goal of "documenting through field investigations, the occurrence of at least 90% of the species of birds currently estimated to exist in the park". In addition, we detected 3 species that were not expected to breed in the Preserve (Long-billed Dowitcher, Least Flycatcher, and Solitary Vireo) and found higher numbers for several species thought to be rare in the area (e.g. Olive-sided Flycatcher, Western Wood-peewee, Yellow-bellied Flycatcher, Townsend's Solitaire, and Townsend's Warbler).

The success of our inventory was due to several factors. First, stratification of blocks by ecological subsection and points by detailed ecological units helped us sample all representative habitat types in the Preserve. Second, our seasonal and daily sampling frames were appropriately chosen to target the periods when most species were present and actively singing, calling, or displaying. Third, our use of longer point count periods (8 minutes) allowed us to detect species that would have otherwise been missed with shorter counts (5 minutes). Finally, our meticulous preparation of logistics and training of personnel enabled us to efficiently survey a large Preserve with minimal access in a short period of time (3 weeks).

Timing of Surveys

Time of day

We found that bird detection rates were highest between 0300 and 0700 h with peak detection between 0430 and 0500 h (Table 5) and that detection rates did not differ appreciably between the sampling hours of 0230-0930 h. Several single-species studies conducted at high latitudes similarly found that peak bird activity occurred between 0300 and 0700 h. In a study conducted 175 km (105 miles) northeast of Fairbanks, Alaska, male American Tree Sparrows produced the greatest number of songs between 0200-0600 h but were still actively singing from 0600 to 1000 h (Weeden 1966). White-crowned Sparrows in Fairbanks, Alaska (65° N Latitude) were heard singing at nearly all times of the day during the nesting season but reached peak singing rates at 0300 h (King 1986); similarly, the peak detection interval for all birds in this study was 0430-0459 h (Table 5). Maximum singing rates for Golden-crowned Sparrows at 62° N Latitude [80 km (48 miles) north of Anchorage, Alaska] occurred from 0100 to 0400 h (Holmes and Dirks 1978). Singing rates for these Golden-crowned Sparrows peaked at 0300 h (>10 songs/minute) and a moderate rate (4-6 songs per minute) was maintained from approximately 0400-2100 h.

Seasonal changes in detection

We based our seasonal sampling timeframe on the June 10 through June 30 recommendation found in the Boreal Partners in Flight Protocol for off-road point count surveys in Alaska (Handel 1999). Surveys commenced on June 8 and finished up on June 30 in 1999 and based on the first year of data collection, we started on June 5 and finished on June 26 in 2000. These dates correspond well to the June 5 to June 27 dates which are considered to be optimum periods to survey birds near Great Slave Lake in Northwest Territories, Canada (61º N Latitude; Carbyn 1971).

During our survey, the number of birds detected was not correlated to date, suggesting this was a stable sampling frame when the majority of breeding species had arrived and established territories. However, our data did show a seasonal decline in the number of species detected per point. We attempted to further examine this seasonal decline in detectability by sampling a single route repeatedly between June 15 and 26, 2000, but were unable to find a strong correlation between the number of birds detected and date or between the number of species detected and date. Since the repeated route was at a low elevation in the Preserve, these results support our findings from the larger inventory that neither the number of birds nor the number of species detected per point at low elevations were correlated to date ($P = 0.35$ and $P = 0.25$, respectively). Alternative hypotheses that either song duration or singing frequency declined over time on the repeated route was not tested.

The declines we found in the number of birds and the number of species detected per point by date at high elevations (>800 m) indicated that surveys at these elevations should be completed early in the breeding season to maximize numbers of individuals and species detected. Some migrant alpine species that breed in the Preserve, e.g. American Pipit, Horned Lark, Townsend's Solitary, and Gray-crowned Rosy Finch, have been heard singing at high elevations in the Preserve as early as the first week of May when only south facing slopes were bare of snow (S. Swanson, pers. obs.). Carbyn (1971) contended that breeding periods of migratory birds in northern latitudes are by necessity synchronous because of the short summer, but Best (1981) found that breeding seasons generally are shorter at higher altitudes and higher latitudes. Given the already short latitudinal summer season, subarctic and arctic birds found at higher elevations in the Preserve may have to risk possible inclement weather early on to successfully fledge a brood.

On the repeated route, several species demonstrated significant trends ($P < 0.05$) in the number of individuals detected by date. Orange-crowned Warbler and Varied Thrush detections declined in number over the course of the repeated samplings while White-crowned Sparrow detections increased. Both Orange-crowned Warbler and Varied Thrush likely produce one brood per year at northern latitudes, but White-crowned Sparrows are capable of producing 2-3 broods, though one is thought to be most common in the far north (Ehrlich et al. 1988). In the Anaktuvuk Pass area of Gates of the Arctic National Park and Preserve (68º N Latitude), White-crowned Sparrow pairs simultaneously were found with fledglings, nestlings, eggs, and building nests on the same study site (Swanson 1997). If White-crowned Sparrows were producing more than one brood per season, the end of our repeated surveys may have corresponded with renewed territory advertisement for a second nesting period.

Point Count Length

Our results suggest that count duration was important in helping us meet our inventory goal. If we had adopted a 5 minute rather than 8 minute count for our surveys we would have missed 20% of individuals and 11% of the species we encountered in the study.

The 11% increase in the number of species detected during the final 3-minute interval was particularly important because one of our objectives was to inventory all breeding bird species in the Preserve. Of the 9 species detected only during the 5-8 minute period, 4 were raptors, 2 were waterfowl, and the other three species with single observations were restricted to particular habitats (Black-backed Woodpecker and Ruffed Grouse) or were rare (Pine Siskin) in the Preserve. One of the 2 Gray-crowned Rosy Finch detections occurred during the 5-8 minute period, and detection of this cryptic species which forages quietly on rocky talus slopes also necessitates longer count duration. A positive relationship between count duration and the occurrence of species with relatively low detection probabilities was also found by Dettmers et al. (1999), further demonstrating that count duration can have a large influence on inventory results.

RECOMMENDATIONS FOR CONDUCTING LARGE-SCALE BIRD INVENTORIES USING VARIABLE CIRCULAR PLOTS

Determine the daily sampling period for the area being sampled prior to fieldwork.

We recommend conducting a pilot study to determine the daily sampling period for the area being surveyed. The daily survey interval used in this inventory project was derived from a 1998 pilot study that examined 24-hour bird activity/detection patterns (S. Swanson 1999). In the pilot study, we obtained >70% of our detections of individuals between 0200 h and 1130 h. Due to physical constraints imposed by traveling in rough terrain, we limited the survey interval to 0200-1000 h in 1999 fieldwork and further restricted it to 0230-0930 h for 2000. This further reduction in inventory time was due to relatively low numbers of birds being detected between 0200-0230 h and 0930-1000 h in 1999 and the number of injuries and exhaustion levels of crews in 1999.

Prepare detailed field maps with routes and points apportioned prior to fieldwork.

The first step of this inventory was development of an ecological subsection map for the Preserve. Using this map, we selected our primary and alternative blocks for sampling, determined the point distribution by detailed ecological unit within blocks, and plotted the length and direction of transect routes. We identified campsites from aerial photos and prepared field maps detailing these sites, points, transects, and block boundaries over a topographic base. The number of points needed in each detailed ecological unit of the block being surveyed was listed on the field map in case alternate campsites had to be used. This occurred frequently when the helicopter could not land where intended or other conditions made the pre-selected campsite unusable. Changing campsite locations necessitated changing survey routes, and crewmembers needed to sufficiently understand the sampling scheme and have the orienteering skills to make these changes.

Alternate blocks were important in dealing with unforeseen situations requiring discarding a block (such as wildfire, bear problems, flooding, snow, etc.) and enabled us to quickly move to new areas without compromising our sampling design. Alternate blocks not used in the first year were put back into the pool of blocks eligible for selection the following year.

Arrange logistics, field equipment, and communications for field crews prior to fieldwork.

Logistics in this study involved scheduling training, helicopters, movement of crews, food preparation, and food drops. Each crew was assigned a group of sample blocks in relatively close proximity and based on this information, we were able to establish a helicopter schedule. Movement of crews was also dependent on block location, elevation, snow cover, and the number of transects in the block. Blocks on the Preserve boundary often contained land outside the Preserve that was not sampled and therefore had fewer transects and could be surveyed in less time than blocks with a full allocation of transects. Based on results from this inventory, high elevation blocks should be sampled early in the season since the number of birds and species detected declined over time during our inventory.

Crew physical limitations should also be considered when setting up field schedules. The general sampling schedule in this inventory was to be transported to a block, complete the 3 survey transects in the block on the following 3 days, and be moved to the next block on the fourth day. This proved to be a difficult schedule given the 0230 h start time, the rugged terrain, and the requirement of sleeping during daylight hours. Heat, rain, and mosquitoes were also obstacles. It often took 10 hours to complete a survey transect and return to camp. We had 3 knee injuries in the first field season, two requiring evacuation. To improve our safety record in year two, we included 2 rest days in the 24 day field session; shortened our daily survey interval; supplied walking sticks; and hired an extra person to rotate between crews if injury or illness dictated a replacement. We also resorted to accessing all sites by helicopter, since care and maintenance of a boat and travel times between blocks absorbed substantial time and energy of field crews.

Field equipment was borrowed, purchased or cleaned/repaired before crews arrived. This allowed us to focus on training once crewmembers were hired and ensured that all instruments necessary for data gathering were available and functioning. Plan on a large supply of batteries. Develop a datasheet that is easy to use in the field, weatherproof (print on waterproof paper), and contains all necessary data collection prompts and codes. Our datasheets were tested and revamped during training sessions as questions arose on information being recorded, code definition, and layout.

We established emergency and daily radio or satellite phone check in and communication procedures to ensure crew safety and provide for information transfer. Crews were required to report to our base of operations by radio or satellite phone each day at noon. A satellite phone was necessary for areas of the Preserve not within range of the radio repeater system. NPS operations staff monitored radios 24 hours per day in case of emergency.

Hire physically fit field personnel with previous bird survey experience.

The physical demands of conducting 2-4 mile transects on foot in rugged terrain require physically fit individuals. We encountered numerous injuries in the first year and had to evacuate several people from the field due to knee injuries. Crew members also had to remain functional despite lack of sleep after working from approximately 0200 h to 1100 h and attempting to sleep in tents during the hot part of the day for several weeks. Personnel should be hired that have previous experience working in remote field locations and a record of remaining cheerful under difficult field conditions.

Recruiting crewmembers with previous bird survey experience is imperative, as is rehiring previous crewmembers in multi-year inventories. Seven crew members in 1999 had previous bird survey experience, and 5 of the 1999 crewmembers returned to work on the 2000 inventory effort. We paired experienced birders with less experienced crewmembers for training and survey work.

Adequately train crews in all aspects of the inventory effort.

Training was a critical aspect of this project and encompassed 3 weeks. We trained crews in bird identification (visual and aural), distance estimation, plant identification and habitat categorization, data collection/recording, park operations (communication systems, regulations, and equipment use), and safety procedures (bears, first aid, helicopter, and shotgun).

Extensive time was spent in various habitats around Fairbanks with experienced observers identifying birds by song and sight prior to the field effort. Bird identification training in the office involved using the *Bird Songs of Alaska* Compact Disk (Peyton 1999) in combination with *Bird Song Master 2.2* Software (Micro Wizard, 5277 Forest Avenue, Columbus OH 43214-1305). The *Bird Song Master 2.2* Software allows the user to select a bird or group of birds and play the associated songs or be quizzed on the songs in a random order. We carried The *Bird Songs of Alaska* Compact Disk and a battery-powered CD player in the field to verify songs and to become familiar with vocalizations that were difficult to learn. A shotgun microphone and small tape recorder were used to record unusual or unidentified bird vocalizations. These recordings were then audio-processed and stored on Compact Disk for archival and verification purposes. Bird field guides were on hand at all times for visual confirmation of species.

Once crewmembers were comfortable with bird identification, we began training them to estimate distances to birds. Several strategies were involved with this training. First we practiced pacing distances from a known point to a marker or designated target and then measuring to confirm the distances. Once paces were standardized, we began estimating distances visually and pacing them to confirm. This process was repeated in open and closed habitats since the amount of vegetation can significantly influence the distance estimated. Finally, we began estimating distances to birds, placing them in distance categories and pacing them for confirmation. Training in distance estimation is very important for obtaining accurate detection functions and density estimates. Crewmembers often found it necessary to recalibrate distance estimations when moving between blocks with different habitats. Use of a range finder is also very helpful when estimating distances, particularly in open tundra habitats (S. Swanson 2001). The range finder can be used to determine distances to several landmarks for calibration purposes, and bird locations are then compared to these distance markers during a survey.

Training to collect habitat data consisted of plant (tree, shrub, forb) identification using vegetation keys and practicing classification of vegetation structure (percent cover, height, and landcover type). This was also done in varying habitats in the Fairbanks area, where measurements and classifications were compared between crewmembers to standardize the data being recorded. The habitats we trained in near Fairbanks were comparable to those encountered in the Preserve.

After considerable training with bird and vegetation identification, we began practicing point count transects using the datasheets and codes found in Appendix III. Training transects were placed in different habitat types and run by crewmembers who were going to be working in the field together. We also practiced navigation using topographic maps, compasses, handheld Garmen Global Positioning System (GPS) units and military Precision Lightweight Global Positioning Receivers (PLGRs). The more accurate PLGRs were used to establish point count locations while the commercial grade Garmen GPS units, which had significantly lower battery requirements, were used for navigation between points. Point count locations were recorded and stored in PLGR memory in the field and downloaded into a Geographical Information System in the office.

Because helicopters were used as the major means of access, all crewmembers were required to have the federal government B-3 helicopter safety training or the equivalent before going into the field. Bear safety and shotgun training proved to be crucial as several camps were torn up and bears were encountered in close situations on several occasions. We carried shotguns for safety but never used them for defense against bears during the inventory.

Preplan data management and analysis procedures before collecting data.

Upon return from the field, crewmembers entered and proofed all data collected during the season. We transferred all data into an electronic database by the second week of July, and began data analysis and report writing shortly thereafter. We entered and proofed data in Microsoft (MS) Excel and later converted all data files into an MS Access database. Field datasheets were stored in fireproof file cabinets as were back up copies of all electronic databases.

The program DISTANCE was used to develop detection functions to estimate density for 98% of the individuals detected during the 2 years of fieldwork. Initial setup and programming of the software was time consuming but, with the help of US Geological Services-Biological Research Division scientists, we were able to obtain density estimates, with confidence intervals, for 36 of the species occurring in the Preserve. These density estimates will provide the baseline against which future changes in population numbers of these species can be measured.

We report univariate analysis of several structural habitat components in this report. It is likely that habitat selection involves both structural and floristic variables and that the relative importance of these variables varies among species. We anticipate obtaining a more accurate picture of species habitat associations by looking at combinations of our structural and floristic variables through multivariate analyses in the future.

Obtain adequate funding to cover inventory costs.

The cost for a startup year for this breeding bird inventory was approximately $121,450. This figure includes training, field, and data entry/proofing costs (Appendix IV). It does not include salaries of permanent and term staff conducting project planning, ecological map preparation, personnel hiring, database development, data analysis, report writing, or conference presentations.

Sixty percent of this inventory's cost was for salary and per diem for 9 people, with logistics accounting for 23% of the total and equipment purchase accounting for 16%. Costs for housing for seasonal employees from out of town was comparably small and amounted to $1400 or 1% of the total inventory cost per year. Logistical costs are dependent upon access means—fixed wing or boat would be cheaper than helicopter transport if such means were feasible; however, we found that they were not viable options in the Preserve. Equipment costs during the startup year will vary, depending on what resources are already available.

Numbers and grade levels of field staff as well as sampling intensity largely influenced the cost of this inventory. Use of volunteers and Student Conservation Association (SCA) Research Assistants would lower the costs of salary expenses. An SCA Research Assistant was used in both years of our study, but in this cost analysis exercise, we replaced them with GS-5 level seasonal employees to reflect costs of a survey conducted by fully paid staff. The SCA Research Assistants were paid per diem to cover food and personal gear needs. Each block sampled under our scenario (9 field crewmembers and 20 blocks per year) cost $4290 to survey which equates to $120 per point surveyed. Reduction in the number of blocks sampled would reduce the cost of the inventory but may result in inadequate coverage of the administrative unit being surveyed.

CHAPTER 2. DENSITY ESTIMATION

We determined that to achieve our goal of developing a long-term monitoring protocol for birds in the Preserve, we needed to produce density estimates (pairs/ha) with measures of variance for as many bird species breeding in the Preserve as possible. These density estimates could then serve as baseline information on population size and distribution for future comparisons. This chapter discusses the results of the analysis we used to accomplish this objective.

INTRODUCTION

Being able to statistically detect change over time in bird population numbers is a primary goal of a bird monitoring plan. Count data (birds/point) and density estimates (pairs/ha) are commonly used to assess changes in the size of bird populations. Bird detection is a crucial component of both types of data. The number of detections recorded for a species is a function of true density and the probability of detection. Probability of detection is affected by many factors including how birds respond to human presence in its vicinity; observer ability to hear, see, or identify species; and environmental variables such as weather, vegetation, and terrain. Researchers must minimize the effects of these factors to ensure that the true density has the greatest influence on the actual number of birds detected.

Count data (birds/point) represent some unknown proportion of the actual number of birds present at each point since we cannot assume that all birds present are observed (Lancia et al. 1994). Count data do not incorporate probability of detection or the effective sampling area surveyed and therefore often produce underestimates of actual abundance. This type of data can be used for population indices, though changes in the proportion of birds counted can be mistaken for differences in population size.

To translate count data into population size estimates, the fraction of total birds present and detected must be estimated (Lancia 1994). Collecting information on the distance to birds in addition to the normal count data (as with variable circular plot techniques) allows for an unbiased estimate of population density by correcting the counts with the probability of detecting a bird as a function of its distance from the observer (Buckland et al. 1993, Lancia 1994). This distance sampling technique allows for the estimation of density and associated variance that can be used to monitor species over time. We incorporated distance sampling theory, methods, and programming in the design, data collection and analysis portions of this study.

ANALYTICAL METHODS

Calculating densities of breeding birds

We used the program DISTANCE version 3.5 (Buckland *et al.* 1993) to model the probability of detecting breeding birds as a function of their distance from observers (detection function hereinafter). Almost all avian detections were of singing, territorial males, which we assumed represented breeding pairs. For each species with at least 20 observations (36 of 87 species detected during surveys) we used all individuals detected during all surveys and calculated frequency statistics and fitted a preliminary model of the detection function. We then examined the preliminary models for evidence of clustering of observations at particular distances and determined whether observations at large distances were confounding estimation of the detection function near distance zero. We grouped adjacent interval classes to control for clustering and to improve the fit of the model. We controlled for the confounding effects of observations at large distances by eliminating data beyond the maximum distance interval with an estimated detection probability less than 0.1 (Buckland et al. 1993).

Next, we modeled the detection function of each species by fitting the pooled, truncated data to a uniform, half-normal, and hazard rate key-detection function. We then examined the improvement of each function with higher order cosine, polynomial, or Hermite-polynomial adjustments and calculated Akaike's Information Criterion (AIC) to compare the fit of the different models (Buckland et al. 1993). We selected the model with the lowest AIC value when the difference in AIC between models exceeded one. When the difference in AIC was less than one, models were considered equivalent (Burnham and Anderson 2002) and we selected the model with smallest coefficient of variance for the detection function. We then estimated density of birds for the Preserve with and without the stratification of survey points to detailed ecological units (D. Swanson 1999).

Estimation of density without stratification.

In the unstratified model we treated block as our sampling unit and for each species calculated breeding density by

$$D = \frac{n \cdot h(0)}{2 \cdot \pi \cdot k}$$

where

n = total number of birds detected in all blocks after truncation,
k = total number of points surveyed, and
$h(0)$ = the slope of the probability density function of detection distances evaluated at distance zero calculated as the inverse of the integral of the measured distances,

$$\frac{1}{\int_0^w r \cdot g(r)dr}$$

where

w = truncation point and r = radial distance of the bird from the observer.

Variance of breeding density was calculated by

$$\mathrm{var}(D) = D^2 \cdot \left[\frac{\mathrm{var}(n)}{n} + \frac{\mathrm{var}[h(0)]}{[h(0)]^2}\right]$$

where

$$\mathrm{var}(n) = k \cdot \frac{\sum k_i \left[(n_i / k_i) - (n/k)\right]^2}{i-1}$$

and

n_i = total number of birds detected in block i after truncation,
k_i = total number of points surveyed in block i, and

i = total number of blocks surveyed.

Estimation of density with stratification.

For each stratum (detailed ecological unit) we pooled points within blocks and treated blocks as the unit of sampling. We then estimated breeding density for each stratum by

$$D_j = \frac{n_j \cdot h(0)}{2 \cdot \pi \cdot k_j}$$

where

n_j = total number of birds detected in stratum j after truncation, and
k_j = total number of points surveyed in stratum j.

Following Buckland et al. (1993), we estimated variance in D_j within each stratum by

$$\text{var}(D_j) = D_j^{\,2} \cdot \left[\frac{b}{n_j} + \frac{\text{var}[h(0)]}{[h(0)]^2} \right].$$

Because var(n_j) is an additional parameter to be estimated, we introduced further parsimony into the model by using a common dispersion factor (b, also called variance inflation factor) across strata to control for random sampling error in detecting birds among strata and was calculated by

$$b = \frac{\sum (i_j - 1) b_j}{\sum (i_j - 1)}$$

where

i is the number of blocks in stratum j in which the species was recorded

and

$$b_j = \frac{\text{var}(n_j)}{n_j}.$$

Variance in the number of birds sampled among blocks within a stratum was calculated by

$$\text{var}(n_j) = k_j \cdot \frac{\sum k_{ij} \left[(n_{ij} / k_{ij}) - (n_j / k_j) \right]^2}{i_j - 1}$$

where

n_{ij} = number of birds detected in block i in stratum j after truncation,
k_{ij} = number of points surveyed in block i in stratum j, and
i_j = total number of blocks within stratum j.

Next we calculated an unbiased estimate of density for the entire study area by taking the average of the stratum estimates weighted by area (Cochran 1977, Buckland et al. 1993) by

$$D = \frac{\sum A_j \cdot D_j}{A}$$

where

A_j = area (ha) of stratum j and $A = \sum A_j$.

Following Buckland et al. (1993), we then estimated the variance of D by

$$\mathrm{var}(D) = D^2 \cdot \left[\frac{\mathrm{var}(M)}{M^2} + \frac{\mathrm{var}[h(0)]}{[h(0)]^2} \right]$$

where

$$M = \frac{\sum A_j \cdot M_j}{A},$$

$$M_j = \frac{n_j}{k_j},$$

$$\mathrm{var}(Mj) = M_j{}^2 \cdot \frac{b}{n_j}, \text{ and}$$

$$\mathrm{var}(M) = \frac{\sum A_j{}^2 \cdot \mathrm{var}(M_j)}{A^2} + \mathrm{Cov}(M).$$

For those blocks containing more than one strata we calculated a weighted covariance term Cov(M) to account for correlations in the number of individuals encountered per point (encounter rate) among strata. For each pair of strata (h, j) we calculated the covariance of the mean encounter rates (M) across all blocks in the Preserve by

$$\mathrm{Cov}(M_h, M_j) = \frac{1}{i(i-1)} \cdot \sum \left(\frac{n_{ih}}{k_{ih}} - \frac{n_h}{k_h} \right) \cdot \left(\frac{n_{ij}}{k_{ij}} - \frac{n_j}{k_j} \right)$$

where i = total number of blocks, and then followed Cochran (1977:92) and calculated the total weighted covariance by

$$\mathrm{Cov}(M) = 2 \cdot \sum^{h} \sum^{j>h} W_h \cdot W_j \cdot \mathrm{Cov}(M_j, M_j)$$

where

$$W_h = \frac{A_h}{A} \text{ and } W_j = \frac{A_j}{A}$$

are the relative areas of the strata within each pair. Finally, we calculated 95% confidence intervals around estimates of mean density (Satterthwaite 1946, Milliken and Johnson 1984, Buckland et al. 1993) for each species by

D / C, $D \cdot C$

where

$$C = \exp\left[t_{\mathrm{df},\, 0.05(2)} \cdot \sqrt{\{\mathrm{var}(\log_e D)\}} \right],$$

$$\mathrm{var}(\log_e D) = \log_e \left[1 + \frac{\mathrm{var}(D)}{D^2} \right],$$

exp = natural exponential, and

$$\mathrm{df} = \frac{[\mathrm{cv}(D)]^4}{\frac{[\mathrm{cv}(M)]^4}{i-1} + \frac{\{\mathrm{cv}[h(0)]\}^4}{n}}.$$

Mean breeding bird densities were also estimated for floodplain, lowland, hill and bluff, mountain valley, and mountain tundra landform categories created by aggregating similar detailed ecological units (Table 11).

RESULTS

Estimates of average breeding density (pairs/ha), total Preserve-wide abundance (number of pairs), and 95% confidence intervals were calculated for 36 species (Table 12). These 36 species represented 98% of all individuals detected during the inventory. Coefficients of variation around the estimates were substantially reduced for many of the 36 species examined when park-wide density estimates were based on stratified rather than unstratified data. Stratification by detailed ecological units improved precision of the estimates (decreased variances) for 34 species (mean = 8.0 ± 6.9%; Table 13) and decreased precision for 2 species (mean = -1.3 ± 0.6%). Twenty-nine species had ≥60 detections before truncation, the recommended minimum number of detections for computing density estimates (Buckland et al. 1993). The other 7 species for which density estimates were calculated had between 21 and 31 detections. The detection functions for these species had high coefficients of variation and density estimates had correspondingly large confidence intervals (Tables 12 and 14).

Based on density estimates, the five most abundant species in the Preserve were Yellow-rumped Warbler, Dark-eyed Junco, White-winged Crossbill, White-crowned Sparrow, and Boreal Chickadee, respectively (Table 12). By summing the density estimates for each species in the major passerine taxonomic groups, we found that sparrows had the highest density (1.3 pairs/ha) of any group detected in the Preserve (Table 12). Dark-eyed Juncos accounted for over half of the sparrow density in the Preserve. The warbler group followed the sparrow group with a density of 0.9 pairs/ha, largely due to the high density of Yellow-rumped Warblers (the most abundant bird in the Preserve). Following warblers in order of decreasing density we found the thrush and flycatcher groups with densities of 0.6 and 0.1 pairs/ha, respectively.

Determination of the most abundant species in the Preserve was quite different depending on whether relative abundance was measured by counts (birds/point) or density estimates (pairs/ha) (Table 15). For instance, Boreal Chickadee was ranked twenty-three when relative abundance was measured by counts but was ranked as the fifth most common species based on density. Conversely, Common Snipe was heard more frequently than its density estimate would suggest; it ranked eighteenth in relative abundance by counts but thirty-sixth by density estimate. These differences are closely linked to the species' effective detection distances and their effect on detection function modeling, with Boreal Chickadees primarily being detected at close range and Common Snipe being detected primarily at greater distances.

We generated mean breeding bird densities (pairs/ha) by detailed ecological unit for 36 species in the Preserve (Appendix V Tables); these calculations were overlaid on the ecological map for the Preserve to produce density maps (Appendix V Figs.). We also calculated mean breeding bird densities by species for the following landform aggregations of detailed ecological units: floodplain, lowland, hill and bluff, mountain valley, and mountain tundra (Tables 16-20). In the floodplain units, we found the six most abundant bird species to be Dark-eyed Junco, White-winged Crossbill, Yellow-rumped Warbler, Boreal Chickadee, Gray Jay, and Swainson's Thrush, respectively (Table 16). Dark-eyed Junco, White-winged Crossbill, Yellow-rumped Warbler, Boreal Chickadee, and Gray Jay densities were also among the most common species in the lowland, hill and bluff, and mountain valley units (Tables 17-19). Orange-crowned Warbler density was fourth highest in the lowlands (Table 17), and White-crowned Sparrow and American Tree Sparrow ranked third and fourth, respectively, by density in the mountain valley units (Table 19). In the mountain tundra units, we found sparrows (White-crowned Sparrow, Savannah Sparrow, American Tree Sparrow, Dark-eyed Junco, and Lapland Longspur) plus the American Pipit to be the most abundant species (Table 20).

Peak densities for individual thrush species occurred at different elevations. We found the highest density of Swainson's Thrush in the floodplains, the lowest elevation landform in the Preserve (Tables 16-20). Moving up in elevation, Hermit Thrush density was highest in the lowlands (Table 17) and the highest densities of Varied Thrushes and Townsend's Solitaires were in the hill and bluff landform (Table 18). The highest densities for both American Robin and Gray-cheeked Thrush occurred in the mountain valleys (Table 19). Northern Wheatears were found only at high elevation in the mountain tundra landform (Table 20).

DISCUSSION

Using variable circular plot techniques with distance estimation, we were able to calculate density (pairs/ha) for 36 (27%) of the 134 bird species estimated to breed in the Preserve. With our sampling intensity we were not able to obtain enough detections to produce density estimates for the other 49 species detected at count stations during the inventory. Though we were able to obtain relative abundance information by counts (birds/point) for 86% of the species expected to breed in the Preserve (90% was our objective; Chapter 1), we were not able to reach this relative abundance goal with density estimation (pairs/ha). However, the species we did obtain density estimates for accounted for 98% of the individuals we detected.

Species that we were not able to develop density estimates for were those that: 1) are most active at times of day when we were not conducting surveys (i.e., soaring raptors, swallows); 2) are located in rivers and large waterbodies (i.e., waterfowl); 3) are patchily distributed (i.e., American Dipper, Snow Buntings, shorebirds); 4) occur in very low numbers in the Preserve (i.e., Least Flycatcher, Chipping Sparrow, Arctic Warbler, Smith's Longspurs); or 5) are not vocal during the time of year our survey was conducted (i.e., early nesting shorebirds, owls, woodpeckers). Specific studies would have to be designed to estimate densities for these species, but basic location and distribution information obtained from this inventory could assist in designing a more targeted sampling approach for them.

We found Yellow-rumped Warbler, Dark-eyed Junco, and White-winged Crossbill, respectively, to be the 3 most abundant species in the Preserve by density estimation. Similarly, in spruce forests in the Copper River Basin, Alaska, density estimates indicated that Dark-eyed Junco, Yellow-rumped Warbler, and Boreal Chickadee, respectively, were the most abundant species in spruce stands (Matsuoka et al. 2001). Ten of 18 bird species found in both areas bred at higher densities in the Copper River Basin than on the Preserve (Matsuoka et al. 2001), potentially because spruce forests were targeted in the Copper River study. Varied Thrush, Orange-crowned Warbler, Wilson's Warbler, White-crowned Sparrow and Pine Grosbeak all had higher densities on the Preserve than in the Copper River Basin. Gray Jays, Lincoln's Sparrow, and American Robin densities were nearly equal in both areas.

The 3 most abundant taxonomic groups in the Preserve (based on the sum of their collective density estimates) were sparrows, warblers, and thrushes, respectively. Within these taxonomic groups there was a great deal of variability in the average densities of individual species (Table 12). Paton and Pogson (1996) similarly found that sparrows and warblers comprised the most abundant species in their study area in Denali National Park, Alaska, as did Matsuoka et al. (2001) in the Copper River Basin.

Distance Estimation Procedures

The accuracy of our density estimates was largely influenced by the number of individuals encountered for each species. During analysis, some observations were further eliminated from the analysis when they were distant from the observer and adversely affected estimation of the detection function near distance zero. This truncation process reduced the number of detections used for density estimation for all species except Hermit Thrush (Table 14, Appendix I). The Rock and Willow Ptarmigans each had 21 field detections, but only 16 and 13 detections, respectively, went into the calculations of density after truncation (Table 14). As the number of detections of a species decreased, the coefficients of variation around the estimates of average densities increased (Tables 12 and 14). The number of detections for Rock and Willow Ptarmigan were the lowest we used, and the coefficients of variation around their estimates of average density were correspondingly the largest among the species analyzed. Those species with the greatest number of detections before and after truncation (e.g. Yellow-rumped Warblers, Dark-eyed Juncos, and White-crowned Sparrows) had the smallest coefficients of variation around their estimates of average density (Tables 12 and 14).

The greatest difference in the coefficients of variation between the stratified and unstratified estimates of density lay, primarily, with those species that are habitat specialists (Table 13). Willow Ptarmigan exhibited the greatest difference in precision between stratified and unstratified estimates of densities of any of the species we examined (40%; Table 13). We found Willow Ptarmigan in 4 of the 28 detailed ecological units and 81% of their detections were restricted to 2 detailed ecological units (Three Fingers Subalpine Basin and Upper Charley Mountains—Gentle Ridges), indicating specialized habitat requirements. The difference between stratified and unstratified coefficients of variation also was high for Hermit Thrush, American Tree Sparrow, and Northern Waterthrush. These species were found in a greater number of detailed ecological units (11, 9 and 8 units, respectively), but $\geq$72% of all the detections for each of these species were contained within 3 detailed ecological units, also indicating specific habitat requirements. Species with little difference between their stratified and unstratified coefficients of variation (Table 13) were found in multiple detailed ecological units (Tables 8-10) and had a wider distribution in the Preserve. Olive-sided Flycatchers, Townsend's Warblers and Boreal Chickadees were detected in

>14 detailed ecological units, and only 48%, 59% and 65% of their detections, respectively, were contained within the 3 detailed ecological units with the greatest number of detections for each of these species.

Aggregating detailed ecological units into landform categories was useful for simplifying land classification by reducing it from 29 detailed ecological units to 5 more widely recognized landforms. Of more importance, it allowed us to obtain larger sample sizes (higher numbers of detections per species by strata) and more robust density estimates at spatial scales smaller than the Preserve. Coefficients of variation around estimates of density at the landform scale were less than those around estimates for the individual detailed ecological units that were aggregated to form a given landform. For example, the coefficient of variation for American Pipits in the mountain tundra landform was 0.20 (*n* = 121 detections; Table AV19), but the coefficient of variation for American Pipit density for the detailed ecological units comprising the mountain tundra landform ranged from 0.25 -2.12 [number of detections (*n*) ranged from 1-83; Table AV19).

Ecological units that are aggregated together into landforms must be ecologically similar to avoid loosing relevant detail in the data or misconstruing density estimate information. By aggregating detailed ecological units into a landform, some detail about where they are most abundant (which detailed ecological unit) also may be lost. For instance, American Pipit density was highest in the mountain tundra landform (0.2983 pairs/ha, coefficient of variation = 0.20; Table 20), which is composed of 5 detailed ecological units with density estimates ranging from 0.0757 pairs/ha (coefficient of variation = 2.12; Upper Charley Mountains-High and Rugged) to 0.4437 pairs/ha (coefficient of variation = 0.25; Upper Charley Mountains—Barren Domes; Table AV19). A species-specific study of American Pipits would obviously occur in the mountain tundra landform, but sampling might target the Upper Charley Mountains-Barren Domes detailed ecological unit within the landform where pipit densities are highest.

Relative Abundance of Birds by Count and by Density

Ranks of relative abundance (pairs/point) compared to average density (pairs/ha) varied considerably (Table 15). For instance, Swainson's Thrush was ranked 4th in relative abundance by count but as 11th in density (Table 15). This disparity results from the detection function used to calculate density estimates. Detection functions calculate the probability of detecting birds as a function of their distance from the observer. Relative abundance calculations do not incorporate either probability of detection or area surveyed. In the case of Swainson's Thrush, many of the detections were relatively far from the observer (77% were > 50 m from the observer), resulting in a lower relative abundance ranking by density than by count. The reverse can be seen with the Boreal Chickadee, whose relative abundance rank was 23rd by count but 5th by density. The higher density ranking resulted from 72% of all Boreal Chickadee detections being <50 m from the observer.

The above differences in count versus density measures of relative abundance also have implications for defining bird community structure. Diversity indices are commonly based on relative abundance of species, but very different communities would be defined depending on whether count or density information was used in the diversity calculations. For instance, nearly twice as many White-crowned Sparrows (0.823 birds/point) were detected as White-winged Crossbills (0.494 birds/point) in the Preserve using counts as the measure of relative abundance (Table 15), but the density of White-winged Crossbills was higher than White-crowned Sparrows (Table 12). If these species were the only ones in a community, we would define a community that was predominantly composed of White-crowned Sparrows using count data versus a community where the two species were nearly equal in number using density. This issue is commonly overlooked in diversity modeling.

MONITORING IMPLICATIONS

By using variable circular plots with distance estimation, we were able to estimate density with 95% confidence intervals for 36 species. Having these baseline densities and associated variances will allow us to evaluate trends over time in populations of these species with a specific degree of confidence. Our estimates of density incorporated the probabilities of detection for each species and therefore provide unbiased estimates of abundance. These detection probabilities can be modeled to incorporate changes in habitat or observers overtime when additional years of data are collected as part of a monitoring program. This is critical for detecting long-term changes in population size as variation in detectability through time related to these and other factors can confound estimates of population change. Such variables are difficult to control for when tracking population trends through indices of abundance (i.e. birds/ point) that furthermore have unaccountable source bias through time. Trends in abundance based on estimates of density over time will have fewer confounding factors and less bias than changes in abundance as measured by index methods and therefore can more accurately track true changes in population size (Buckland et al. 1993, Gibbons et. al. 1996).

Incorporating stratification in our sampling design was a critical component of this study. Stratification of points by detailed ecological unit increased precision of the density estimates, thereby increasing our power to detect changes in population size in the future. In addition, having estimates of species densities for individual strata in the Preserve give us an understanding of species distributions at a scale on which management actions, if needed, could be taken. Being able to determine where (which strata) each species occurs at the greatest density will also be valuable for future species-specific studies and monitoring efforts.

We were able to determine density estimates for 31% of the species encountered during the inventory effort, but these species made up 98% of the total observations. This group of species was dominated by passerines (n = 33 species), but also included two species of ptarmigan and one species of shorebird (Table 12). Passerines in this group encompassed a wide range of taxonomic groups, some represented by multiple species (such as the flycatchers, thrushes, warblers, sparrows, and finches) and others represented by single species (such as pipits, waxwings, chickadees, jays, and larks). These are the species that are most likely to be monitored using the methods we employed.

Taxonomic groups that were not adequately detected and could not be monitored using our design and survey methods include loons, grebes, waterfowl, hawks, falcons, grouse, cranes, gulls, terns, owls, shrikes, kingfishers, woodpeckers, and swallows. Other techniques that have been developed to survey some of these species (Gibbons et al. 1996) should be explored to broaden the number of species that could monitored in the Preserve. Using our methods we will not be able to obtain density estimates for long-term monitoring of passerines that occur in very low numbers, are secretive and therefore hard to detect, or are restricted to very specific habitats in the Preserve. These species include Least Flycatcher, American Dipper, Arctic Warbler, Blackpoll Warbler, Chipping Sparrow, Golden-crowned Sparrow, Smith's Longspur, Snow Bunting, and Pine Siskin. Targeting sampling to specific habitats and time frames or developing new techniques will be necessary to determine trends in population size for these species. Data from our inventory methods could assist in designing these targeted studies by providing location and habitat data (by detailed ecological units) to use in determining appropriate study site locations.

CHAPTER 3. UNIVARIATE HABITAT ANALYSIS

We examined species selection preference and avoidance for 3 habitat structure variables (tree canopy cover, percent coniferous trees, and percent shrub cover) using univariate analysis procedures. This chapter discusses the methods and results of this analysis.

INTRODUCTION

Vegetation structure is an important factor influencing bird habitat use. Deciduous canopy cover, conifer cover, and shrub cover were the first three components of an analysis of bird habitat use variables in aspen forests in Alberta, Canada (52º N Latitude) and these 3 variables accounted for 83.2% of the total variance in that data (Westworth and Telfer 1993). In a similar study in Interior Alaskan taiga, Spindler and Kessel (1980) found that habitat openness (a function of canopy cover), shrub density, canopy thickness and ground cover type accounted for 61.5% of the total variation in bird species distribution. Tree species richness and canopy cover, variation in canopy height, and tree density controlled the first 3 axes of a principal components analysis of habitat structure and bird diversity in a large data set from North American forests (James and Wamer 1982). Using canonical analysis, Bersier and Meyer (1994) found tree cover, shrub cover, and foliage height diversity accounted for the most of the variation in bird habitat use in Brittany, France. Similarly, Verner and Larson (1989) found that foliage volume or total crown volume, which was the sum of tree and shrub crown volumes, was the best predictor of avian species diversity in mixed-conifer forests of the Sierra Nevada in California.

Variables that influence habitat structure and consequent bird habitat use include floristics (the number, distribution, and relationships of plant species; Bersier and Meyer 1994), elevation (Cody 1985, Finch 1991), and forest age or successional stage (Fox 1983, Westworth and Telfer 1993, Kirk et al. 1996). On a large scale, vegetation structure appears to be more important than floristics, but when looking at small-scale sites, floristics may take precedence (Bersier and Meyer 1994). Cotter and Andres (2000) collected basic floristic data to classify vegetation cover types for roadside Breeding Bird Survey sites throughout Alaska; this data was used to examine bird-vegetation associations and will facilitate monitoring future changes in these relationships. Spindler and Kessel (1980) used a combination of vegetation structure and floristics, namely by tree and shrub species, to look at bird habitat use in Interior Alaska.

Elevation influences the composition of trees, shrubs, and graminoids and hence the vegetation structure of an area. Finch (1991) found avian species richness and abundance varied substantially from low to high elevations, with vegetation being more structurally complex and, consequently, bird species richness being greater at low elevations. Bird species and levels of abundance have also been shown to vary between different-aged forests and successional stages. Avian species composition differed with aspen forest maturity in Alberta, Canada (Westworth and Telfer 1993). In Canada, Kirk et al. (1996) found that the highest combined densities of neotropical migrants occurred in old forests and that short distance migrants were most abundant in young forests. Their analysis also determined that the highest abundance of upper-canopy gleaning species was found in old forests and that ground foraging species were most abundant in early successional forests.

The habitat structure resulting from differences in floristics, elevation, and succession is utilized differently between species; it provides foraging sites, nesting sites, perch sites, and protection from weather elements and predators (Cody 1985). Foraging strategies for passerine birds range from flycatchers hawking flying insects from a high perches to warblers and woodpeckers gleaning tree foliage and bark to thrushes and sparrows foraging at the ground-brush level. Trees, particularly mixtures of deciduous and needleleaf species, provide a wide variety of foraging, nesting, and resting opportunities, thereby accommodating a diverse group of avian species. In Sweden, mixed forests are thought to have higher bird density than deciduous forests because they have high insect availability in combination with good predator refuge (Berg 1997). Shrubs add complexity to the foraging specializations possible in a habitat (Verner and Larson 1989). Vegetation type and structure also determines the types of nests that a given habitat can support. Trees are necessary for cavity nesting woodpeckers and chickadees and for species building nests on branches such as thrushes and finches. Shrubs support sparrow and warbler nests built on their branches or stems and in their root mass bases. Herbaceous- or graminoid- dominated vegetation supports grass, sedge, or tussock cup or burrow nests such as those built by sparrows, Northern Wheatears, and American Pipits. Some successional forest stages (particularly mixed deciduous/coniferous stands) have high habitat diversity, providing a variety of structures and materials for nest building as well as different food sources.

ANALYTICAL METHODS

We examined bird species selection or avoidance preference for 3 habitat structure variables: tree canopy cover, percent coniferous trees, and percent canopy cover. We first performed chi-squared tests for each bird species to determine overall use significance of each habitat structure variable. If the chi-square test result was significant, individual categories within each habitat structure variable were tested for preference by computing simultaneous confidence intervals with significance levels corrected for multiple comparisons using the Bonferroni method (α=0.05; Neu et al. 1974, Byers and Steinhorst 1984, Manly et al. 1993). Selection (or preference) for a given habitat structure category occurred when a species was detected there significantly more than expected by its chi-square contingency cell value.   A habitat structure category was selected against or avoided when a species was detected there significantly less than expected. The expected value was based on the habitat structure's occurrence on the 1,415 points sampled and is hereafter referred to as availability. Species were included in the analyses if they were observed within a 50-m radius of the point count location at >5 points. Points with <10% tree cover were excluded from the percent coniferous tree analysis. Analyses of percent tree canopy cover and percent coniferous trees included data from 1999 and 2000 point count surveys, while analyses of percent shrub cover were limited to data collected in 2000.

RESULTS

We examined habitat selection by bird species for percent tree canopy cover, coniferous cover, and shrub cover variables using chi-squared tests (Tables 21, 23, and 25). For each bird species with a significant chi-square result, selection (positive, negative, or not significant) of each cover category was determined using the Bonferroni method (Neu et al. 1974, Byers and Steinhorst 1984, and Manly et al. 1993; Tables 22, 24, and 26).

Tree Canopy Cover

Of the 32 bird species that met the test criteria (bird species was observed within 50 m radius at >5 points) for percent tree canopy cover, 25 species exhibited a use pattern significantly different from what was expected (X^2; $P< 0.05$; Table 21). In general, open tundra species (Rock Ptarmigan, Horned Lark, Northern Wheatear, American Pipit, Savannah Sparrow, and Lapland Longspur) selected against tree canopy cover (Table 22). Thrushes (except the Northern Wheatear) selected for woodland cover types with 10-24% tree canopy cover, though the Swainson's Thrush and Ruby-crowned Kinglet also selected for >24% tree canopy cover. American Robin preferred stands with <10% tree canopy cover.

Among the warbler species examined, Townsend's Warbler selected for the densest tree canopy cover (>24% category), Yellow-rumped Warblers preferred the 10-24% category, and Wilson's Warbler selected for the sparsest tree canopy cover (<10%; Table 22). Wilson's Warbler was the only warbler to use treeless habitat in proportion to its availability. Orange-crowned Warblers used all tree canopy cover categories in proportion to their availability but avoided treeless areas. Within the sparrows, both White-crowned and American Tree Sparrows selected for open areas with <10% tree canopy cover. Dark-eyed Juncos preferred 10-24% tree canopy cover, used other treed categories in proportion to their availability and avoided areas with no tree canopy cover (Table 22). White-winged Crossbills and Pine Grosbeaks targeted ≥10% tree canopy cover habitats and were either found in proportion to or selecting for 10-24% and >24% canopy cover (Table 22).

Coniferous Tree Composition

Of the 25 species that met the test criteria (bird species was observed within 50 m radius at >5 points with >10% tree canopy cover) for examining coniferous tree use, 7 species exhibited a use pattern significantly different from what was available (X^2; $P< 0.05$; Table 23). Hammond's and Yellow-bellied Flycatchers exhibited similar habitat selection patterns, selecting for habitats with ≤25% conifers (primarily deciduous trees), using habitats with 26-89% conifers (mixed coniferous/deciduous stands) in proportion to their availability, and avoiding habitats with >89% conifers (Table 24). Swainson's Thrush selected for the widest range of conifer density (≤89%), but avoided the >89% category. Gray-cheeked Thrush was the only species of the 7 examined that actually selected for habitats with >89% conifers and avoided habitats with ≤25% conifer composition (Table 24). Orange-crowned Warblers preferred habitats with ≤25% coniferous trees, used mixed coniferous/deciduous stands (26-89% coniferous trees) in proportion to their availability, and avoided conifer-dominated stands (>89%). Townsend's Warbler used habitats with ≤89% coniferous trees in proportion to their availability. Both Orange-crowned and Townsend's Warblers avoided habitats with >89% conifers (Table 24).

Shrub Cover

Only data from 2000 was used to examine shrub cover selection, resulting in small sample sizes for many species (Table 25). Shrub cover was used significantly differently from what was expected for 16 of 28 bird species ($X^{2;}$ $P < 0.05$; Table 25). Both Gray-cheeked Thrush and Ruby-crowned Kinglet selected for habitats with <25% shrub cover and used habitats with 25-75% shrub cover in proportion to their availability (Table 26). However, Ruby-crowned Kinglets avoided >75% shrub cover while Gray-cheeked Thrushes used this cover class in proportion to its availability. Wilson's Warbler and Northern Waterthrush both selected for >75% shrub cover, while the Yellow-rumped Warbler avoided this shrub cover class and preferred areas with <25% shrub cover. White-crowned Sparrows and American Tree Sparrows preferred dense shrub cover (>75%) while Juncos avoided those areas. White-winged Crossbills avoided >75% shrub cover but, like Common Redpolls, otherwise used shrub categories in proportion to their availability (Table 26).

DISCUSSION

The fire-driven ecosystem of Yukon-Charley Rivers National Preserve has created a natural mosaic of different vegetation successional stages with varying structural and floristic components, which significantly influences passerine species distributions. We examined species preferences for the 3 structural components that appeared to be key factors in determining species presence or absence based on literature review and the authors' personal observations. Since we collected habitat data within a 50 m radius of the point count location, we used only those bird detections that occurred within 50 m of the observer for these analyses. Only 6% of our total bird detections were within 50 m of the observer. Consequently, many species did not have sufficient numbers of detections (being detected at >5 points) to analyze. Additionally, several species that were detected within 50 m at >5 points had expected values of <5 in greater than 20% of the cells, a situation that compromises the reliability of the Chi-square test and could lead to misinterpretation of the data (Bailey 1980). Test results for these species were reported but flagged as needing to be treated with reservation (Tables 21-26).

Tree canopy cover

We found that Horned Lark, Northern Wheatear, American Pipit, Savannah Sparrow, and Lapland Longspur tree did not select for canopy cover or, consequently, conifer tree composition (Table 22). With the exception of the Savannah Sparrow, these species were found only in open habitats at high elevations above treeline in the Preserve. Savannah Sparrows were also found in the Preserve below treeline in open areas such as wet sedge meadows. Savannah Sparrows generally avoid complete canopy cover (Kessel 1998), favoring grass or open habitat and using shrubs for singing perches (Spindler and Kessel 1980, S. Swanson 1997, Kessel 1998, Cotter and Andres 2000). All of these open habitat species build ground nests and are considered ground-gleaners, eating insects, seeds, and fruit (Ehrlich et al. 1988). Neither nest building activities nor foraging strategies for these species require tree canopy cover.

Varied Thrush, Ruby-crowned Kinglet, and Swainson's Thrush either selected for habitats with >10% tree canopy cover or used them in proportion to their availability

(Table 22). Varied Thrushes are closely associated with total canopy cover and favor heavily shaded habitats, either generated by trees or tall shrubs (Kessel 1998). Tree cover is necessary for Varied Thrushes to glean foliage for insects and to construct their nests (Ehrlich et al. 1988). Ruby-crowned Kinglets were found to be positively associated with forest cover and 90% of their activity is projected to occur in the tree layer (Spindler and Kessel 1980, Cotter and Andres 2000). In this study Ruby-crowned Kinglets preferred habitats with >10% canopy cover, which supports Kessel's (1998) finding that the species favors intermediate canopy coverage. Ruby-crowned Kinglets have been found to prefer coniferous trees regardless of size, though some tree-height spruce (≥5 m) is likely required (Kessel 1998, Cotter and Andres 2000).

Swainson's Thrush selected denser tree canopy cover than did Gray-cheeked Thrush, which avoided >24% tree canopy cover (Table 22). Kessel (1998) found that Gray-cheeked Thrushes tolerate forest canopy where adequate low shrub cover exists, and, as in this study, Cotter and Andres (2000) found them to be fairly common in open habitats of needleleaf woodland. Swainson's Thrushes, however, favored forest habitats with thick canopies and high canopy coverage (Kessel 1998, Cotter and Andres 2000). Nests for both species are primarily built in shrubs, though Swainson's Thrush also builds nests in the lower branches of conifer trees. Both species are ground foragers but Swainson's Thrushes also hawk, hover and foliage glean. These slight differences in habitat structure use and foraging strategy were likely reflected in our findings of high densities of Gray-cheeked Thrushes at higher elevations (mountain valleys; Table 19) than Swainson's Thrushes, which had their highest densities in the Yukon River floodplain (Table 16).

We found that American Robins preferred low tree canopy cover (<10%) and avoided habitats with >24% canopy cover (Table 22). The American Robin was considered a generalist in terms of habitat use by Spindler and Kessel (1980), but they also found that American Robins tended to avoid closed forests and attributed this to dense understory and lack of berry producing shrubs. Cotter and Andres (2000) observed that American Robin was closely associated with forest cover, particularly needleleaf woodland, in the Central Bioregion of Alaska (which includes Yukon-Charley National Preserve).

All four warbler species we examined selected a different tree canopy cover category. Townsend's Warbler selected for the greatest amount of tree canopy cover (>24%), Yellow-rumped Warbler selected for intermediate tree canopy cover (10-24%), Wilson's Warbler selected for sparse tree canopy cover (<10%), and Orange-crowned Warbler showed no preference for any of the tree canopy cover categories (Table 22). Similarly, Cotter and Andres (2000) found that density of both Yellow-rumped and Townsend's Warblers was positively associated with increasing forest cover. Yellow-rumped Warblers favored forested habitats in Interior Alaska taiga and 83% of their activity occurred in the tree layer (Spindler and Kessel 1980). Ninety-five percent of the Townsend's Warblers observed in Spindler and Kessel's study (1980) were in the tree layer. Both species are tree nesters and obtain insects through gleaning on or hawking from trees (Ehrlich et al. 1988).

Wilson's Warblers were most often found in shrub habitats without tree canopy in the Central Bioregion of Alaska and their density was positively correlated to increased shrub cover (Cotter and Andres 2000). Kessel (1998) found that the Wilson's Warbler tolerates forests and tall shrubs if there is adequate medium height deciduous shrub canopy. Habitats with <10% trees in the Preserve often had a substantial shrub component. The shrub layer in the <10% tree canopy cover areas preferred by Wilson's Warbler may have been more central to their habitat selection, since shrubs, thickets, and brush seem to be an important habitat structure component for the ground-nesting Wilson's Warbler (Spindler and Kessel 1980, Kessel 1998, Cotter and Andres 2000),

Avoidance of tree canopy cover ≥10% by White-crowned, American Tree, and Savannah Sparrows has also been observed in other areas of Interior Alaska (Spindler and Kessel 1980, Kessel 1998). White-crowned Sparrows tolerate forest and tall shrubs where an adequate coverage of dense low shrubs is present, but the American Tree Sparrow avoids forests and tall shrubs (Kessel 1998, Cotter and Andres 2000). Spindler and Kessel (1980) found Savannah Sparrows second only to American Tree Sparrows in their preference for open habitats. All three species nest on the ground or low in shrubs and sing from higher perches in the shrubs (Ehrlich et al. 1980, Spindler and Kessel 1980, Swanson 1997). Lincoln's Sparrow generally exhibits a strong selection for open habitat, particularly damp habitats with water, a sedge-grass ground cover, and high brush density (Spindler and Kessel 1980). Lincoln's Sparrows preferred habitats with tree canopy cover <10% in the Preserve, but we found them in a wide range of canopy cover classes (Table 22). The wetland component associated with these sites may be more predictive of the species presence than tree canopy cover.

Dark-eyed Juncos selected the highest tree canopy coverage (10-24%; Table 22) of the 7 sparrow species we examined. Similarly, Dark-eyed Juncos demonstrated a preference for woodlands and forests in Spindler and Kessel's study (1980), and Cotter and Andres (2000) found Dark-eyed Junco density to be positively related to increasing forest cover for this species. Fox Sparrows selected for areas with <10% tree canopy cover, though they also used sites with tree canopy cover >10% in proportion to their availability. Fox Sparrow density has been negatively associated with increasing forest cover in Alaska (Cotter and Andres 2000) and they have been found to favor tall shrub thickets with dense low shrub layers (Spindler and Kessel 1980). However, male Fox Sparrows use high perches for singing and tolerate forests where tall shrub canopy density is adequate (Kessel 1998). Further analysis of our Fox Sparrow habitat data is needed to assess the relationship between the tree canopy cover and their corresponding shrub component at sites where Fox Sparrows were detected.

We found that both White-winged Crossbills and Pine Grosbeaks avoided sites with tree canopy cover <10%, but White-winged Crossbills selected forested sites with >24% tree canopy cover and Pine Grosbeaks preferred woodland habitat with 10-24% tree canopy cover (Table 22). Similarly, Spindler and Kessel (1980) found that White-winged Crossbills demonstrated a clear preference for mature forests (primarily of white spruce upon which they forage extensively for seeds; Ehrlich et al. 1988), and tree canopy thickness was identified as an important factor in determining their habitat use. Pine Grosbeak habitat information from Breeding Bird Survey data suggest an affinity to more open habitats in the Central Bioregion of Alaska (Cotter and Andres 2000), which concurs with our determination that they select more open, woodland habitat.

Percent Coniferous Trees

Both Hammond's Flycatcher and Yellow-bellied Flycatcher selected deciduous forest habitats with ≤25% conifer trees and avoided needleleaf forest habitats with >89% conifers (Table 24). Likewise, Hammond's Flycatcher appeared to be most common in broadleaf and mixed forests in the Central Bioregion of Alaska (Cotter and Andres

2000). In southern Interior Alaska, Hammond's Flycatcher exhibited a primary preference for deciduous forest, with territories being found only in deciduous forest plots and typically in heterogeneous and open habitat (Spindler and Kessel 1980). Little is known about Yellow-bellied Flycatcher distribution or habitat use in Alaska. These flycatchers were most abundant in the fire-prone hill and bluff landform of the Preserve (Table 18) where deciduous trees were more prominent. Several times they were heard simultaneously with Western Wood-Pewees, another deciduous or mixed needleleaf/deciduous forest denizen (Ehrlich et al. 1988) that is uncommon in the Preserve.

Spindler and Kessel (1980) found that coniferous forests (with >90% conifers in the tree canopy) had the lowest breeding bird density and biomass and the fewest number of bird species of all the forest habitats they studied. In this study, only Gray-cheeked Thrush actually selected for needleleaf forest habitats (Table 24). All other species with significant Chi-square test results for percent coniferous trees avoided stands with >89% conifer tree composition. Gray-cheeked thrushes were most abundant in the higher elevation mountain valley detailed ecological units (Tables 19 and AV14), where Black and White Spruce Woodland habitat predominated. On an off-road point count route along the Middle Fork Koyukuk River in Gates of the Arctic National Park and Preserve, Gray-cheeked Thrushes were predictably found where Black Spruce woodland occurred; Swainson's Thrushes were present in all other habitats with higher tree diversity encountered along the route (S. Swanson, pers. obs.). In other Alaska studies, only Gray Jays, Ruby-crowned Kinglets, and White-winged Crossbills have demonstrated clear affinities for spruce forests (Spindler and Kessel 1980, Kessel 1998, Cotter and Andres 2000).

We found that Swainson's Thrush selected for both deciduous forest and mixed needleleaf/deciduous stands but avoided forests with >89% conifers (Table 24). Similarly, Cotter and Andres (2000) found Swainson's Thrush occurrence to be highest in broadleaf forests (forests with >75% deciduous trees), followed closely by mixed forest (needleleaf and broadleaf trees each comprise 25-75% of the total canopy) and needleleaf forest (>75% needleleaf trees), respectively. Kessel (1998) found the highest density of Swainson's Thrush in mixed coniferous-deciduous forest plots where neither deciduous nor coniferous trees comprised >90% of the tree canopy; Swainson's Thrush and Dark-eyed Junco together comprised 48% of the breeding bird density in this habitat type in her study. Results from our study support Cotter and Andres' (2000) conclusion that Swainson's Thrushes in the Central Bioregion of Alaska are common in a variety of forested habitats, especially broadleaf forests.

Orange-crowned Warblers selected deciduous habitats with ≤25% conifers in the Preserve (Table 24). Similarly, Orange-crowned Warblers in the Central Bioregion of Alaska were most common in broadleaf forests, particularly in areas with early successional broadleaf forest (Cotter and Andres 2000). Spindler and Kessel (1980) found that Orange-crowned Warblers favored habitats with a decided willow shrub component, whether they were in open habitat or under deciduous forest canopy. Analysis of the shrub component associated with sites in the Preserve where Orange-crowned Warblers were detected (particularly for sites classified as deciduous) is needed to further define habitat use and preference for Orange-crowned Warblers.

Townsend's Warblers were found in mixed needleleaf/deciduous and deciduous habitats in proportion to their availability in the Preserve but avoided needleleaf habitats (Table

24). According to Spindler and Kessel (1980), Townsend's Warbler is restricted to mature conifer (particularly White Spruce) or mixed coniferous forests with large White Spruce trees in southern Interior Alaska (Spindler and Kessel 1980). Ninety-five percent of the Townsend's Warblers observed by Spindler and Kessel (1980) were in the tree layer, with 60% being located in White Spruce, 31% in Paper Birch, and the remaining 4% in other treed habitats. Most of the habitats with >89% needleleaf composition in the Preserve were dominated by Black Spruce, and due to the fire regime and permafrost levels in the soils, large White Spruce trees are usually found in mixed needleleaf/deciduous or predominantly deciduous stands. Given the Townsend's Warbler's predilection for White Spruce, it is not surprising that they were found in habitats with a decided deciduous component in the Preserve.

White-winged Crossbills in the Preserve preferred mixed needleleaf/deciduous forests (26-89% conifers; Table 24), while Spindler and Kessel's (1980) study in Southcentral Alaska found that White-winged Crossbills exhibited a clear preference for mature White Spruce forests. Mature stands of White Spruce were found primarily in the floodplain and hill and bluff landforms in the Preserve, which is where White-winged Crossbills were most abundant (Tables 16 and 18). These landforms are heavily influenced by wildfire and consequently have a strong deciduous tree component, resulting in primarily mixed needleleaf/deciduous forest vegetation instead of needleleaf. The percentage of conifer trees in the canopy is likely not as important to White-winged Crossbills as the presence of mature White Spruce trees with cones for foraging.

Shrub Cover Selection

Gray-cheeked Thrush exhibited a preference for habitats with <25% shrub cover and were found in habitats with ≥25% shrub cover in proportion to their availability (Table 26). We had anticipated that Gray-cheeked Thrushes would prefer greater shrub cover since Kessel (1998) found them to be strongly correlated with percent low shrub cover in Southcentral Alaska, and Gray-cheeked Thrush abundance in the Central Bioregion increased with increasing shrub cover (Cotter and Andres 2000). In this study, 76% of the Gray-cheeked Thrush detections in <25% shrub cover (n = 17 birds) occurred in the Woodland Needleleaf Moss landcover type. This landcover type had 10-24% tree canopy cover, which was the preferred tree canopy cover for Gray-cheeked Thrush in the Preserve (Table 22). Tree canopy cover may have superseded shrub cover in thrush habitat selection in this landcover type, but further habitat modeling is needed to examine the interactive roles of these structural habitat variables in Gray-cheeked Thrush habitat selection.

Ruby-crowned Kinglets and Yellow-rumped Warblers preferred the habitats with <25% shrub cover and avoided those with dense (>75%) shrub cover (Table 24). Likewise, Cotter and Andres (2000) found that Ruby-crowned Kinglets were positively associated with forest cover and negatively associated with increasing shrub cover. It is likely that shrub cover preference patterns for Ruby-crowned Kinglets and Yellow-rumped Warblers in the Preserve were governed by their preference for tree canopy cover or coniferous tree composition rather than shrub cover.

Species selecting the greatest percentage of shrub cover were Wilson's Warbler, Northern Waterthrush, White-crowned Sparrow, and American Tree Sparrow (Table 24). Wilson's Warblers were frequently detected in shrubby draws and riparian areas, particularly at higher elevations in the Preserve. In the Central Bioregion of Alaska, Wilson's Warbler density was positively associated with increased shrub cover and the species was most often found in shrub habitats without canopy cover (Cotter and Andres 2000). Kessel (1998) found a positive correlation between Wilson's Warblers and woody deciduous shrubs in the 0.6-1.0 m range (low shrubs) and stated that high density deciduous vegetation in the vertical profile of the low shrub layer appeared to be a habitat requirement for Wilson's Warblers.

Northern Waterthrushes in the Preserve selected sites with high shrub cover (>75% cover) and avoided habitats with <25% shrub cover (Table 24). During the breeding season, Northern Waterthrushes occur in close association with water and are particularly abundant in riparian habitats (Pogson et al. 1999). The species was also found to be most common in wet, shrubby habitats in the Central Bioregion of Alaska (Cotter and Andres 2000). The highest densities of Northern Waterthrushes in the Preserve were associated with river and stream locations, where shrub cover is typically dense (Fig. AV26).

White-crowned Sparrow and American Tree Sparrow have also demonstrated preference for shrub cover (particularly for low shrubs) in other Alaskan studies (Spindler and Kessel 1980, Kessel 1998, Cotter and Andres 2000). Though we found that White-crowned Sparrows and American Tree Sparrows exhibited very similar shrub cover use patterns, American Tree Sparrows appeared to have a much more restricted range in the Preserve (Figs. AV27 and AV31). This is likely because White-crowned Sparrows tolerate forest and tall shrub habitats with adequate coverage of dense low shrubs while American Tree Sparrows avoid these areas (Kessel 1998).

RECOMMENDATIONS

More in-depth analysis of the habitat data collected in this study is necessary to adequately determine species habitat preferences. We were able to examine preferences for some bird species within 3 separate structural variables but have no information on the importance of these variables relative to each other. We need to conduct multivariate analyses (such as log-likelihood tests or logistic regression with stepwise selection procedures) that incorporate both structural and floristic factors to develop multivariate models capable of predicting species presence/absence. Variables such as elevation, presence of open water or types of disturbance could also be included in these models.

CHAPTER 4. SPECIES DIVERSITY

We used several different analytical approaches to examine species diversity in the Preserve. This chapter presents information on species richness, abundance distributions, and diversity within and between the Preserve's ecological subsections and detailed ecological units.

INTRODUCTION

Attempts to define and quantify diversity in avian communities have been ongoing for more than 50 years. Many early studies concentrated on basic ecological relationships between birds and the habitats they occupied (MacArthur and MacArthur 1961, Weins 1973, Willson 1974). Today, studies of avian diversity are important tools for developing land management guidelines addressing potential threats (silvicultural practices, altered fire regimes, forest pest management, invasive species, global warming) to avian habitats. We investigated avian diversity in Yukon-Charley Rivers National Preserve in an attempt to: obtain measures of species richness on several scales; determine areas where unique assemblages of species exist; ascertain sample sizes needed for more detailed studies; and calculate baseline data to monitor species and species assemblages over time.

Species diversity is an ecological concept that has been defined and quantified in many different ways (see Magurran 1988 for review). There is a great deal of debate as to how diversity should be measured and what those measurements tell us about the communities being studied (Peet 1974, James and Rathbun 1981, Wolda 1981, Magurran 1988). There are 4 major categories of diversity measures that are commonly found in the ornithological literature (see Magurran 1988 for review). Species richness indices measure the number of species found in a specified sampling unit. Species evenness indices describe the distribution of species abundance. Community similarity indices measure the degree of similarity in the avian community composition between sites. Diversity indices are based on the proportional abundance of species and meld measures of richness and evenness into a single index. In this chapter we explore our data using methods from each of these categories.

The simplest and most common method of looking at species diversity is through some measure of species richness. Richness indicates the number of species in a community (Peet 1974) and is reported as either the total number of species or as a relative measure of the number of species in a community (e.g. species per point or species per site). Direct species counts provide a simple measure of species richness. However, species richness calculations are difficult to use for comparisons between communities because they are inherently dependent on sample size. They also account only for the number of species detected in a specified area and ignore the abundance of those species. Rarefaction is a statistical method that standardizes species richness samples of different sizes and allows comparisons of species abundance between communities. Community similarity indices are another method of examining species richness and provide a means of quantitatively comparing the similarity of species composition between communities.

Species richness estimators take into account only the number of species detected in a specified area and ignore the abundance of those species. Abundance, however, is incorporated in species abundance distribution measures, which frequently use dominance-evenness indices to describe the relative abundance of all species that are detected in a study area. There are many evenness indices available for use (See Magurran 1988 for review) and most are sensitive to the presence of rare species and to overall sample size (James and Rathbun 1981). Dominance indices describe the inverse of evenness and are calculated such that the most common species make the greatest contribution to the index value and rare species do not increase the value significantly. Sample size also affects the results of dominance indices, although there are some exceptions (Wolda 1981).

Many different indices based on the proportional abundance of species (combining richness and evenness) have been developed and used by ecologists since the 1960's (James and Rathbun 1981, Magurran 1988). These indices combine measures of both richness and evenness to produce an index value that indicates the "diversity" of each community (ecological subsection). As with other methods discussed above, diversity indices are sensitive to sample size, assume accurately estimated relative abundance, and ignore differences in detectability among species.

ANALYTICAL METHODS

We employed the analytical methods below to explore avian species richness, abundance distribution, and diversity (index incorporating both richness and evenness) within and between ecological subsections and detailed ecological units in the Preserve. Means are presented ± 1 standard error (SE) and P-values (P) ≤ 0.05 are considered statistically significant. Except for Preserve-wide calculations of site and point diversity (species richness measures), we excluded data from the Snowy Domes ecological subsection for these analyses as only 5 points were surveyed in that subsection.

Species Richness

We measured species richness using both site and point level diversity on Preserve-wide, ecological subsection, and detailed ecological unit scales. Site level diversity was the sum of all species detected at each scale (Nur et al. 1999). Point level diversity was calculated as the mean of the number of species detected at each survey point for each scale. Analysis of variance (ANOVA, Zar 1999) was used to assess differences in numbers of species detected by ecological subsections. ANOVA was also used to examine the relationship between the number of species detected and elevation.

Rarefaction is a back-calculated (post-priori) statistical method of estimating the number of species that would be expected [E(S)] from a random sample of all individuals detected in an area (Heck et al. 1975). We used rarefaction to standardize species richness count data that may have been biased due to differences in numbers of samples or from differences in numbers of individuals sampled. We were then able to estimate the number of species that would be expected to occur with a given level of detections of individuals for each ecological subsection. We calculated E(S) using the computer software EcoSim (Gotelli and Entsminger 2003) according to the following formula found in James and Rathbun (1981):

$$\mathrm{E}(S_n) = \sum \left(1 - \frac{\binom{N - N_i}{n}}{\binom{N}{n}} \right)$$

where S_n = total number of species in a sample of n individuals, and N_i = number of individuals in species i.

The variance around S_n was calculated by the method described in Heck et al. (1975);

$$\mathrm{var}(S_n) = \binom{N}{n}^{-1} \left[\sum \binom{N - N_i}{n} \left(1 - \frac{\binom{N - N_i}{n}}{\binom{N}{n}} \right) + 2 \sum \binom{N - N_i - N_j}{n} - \frac{\binom{N - N_i}{n}\binom{N - N_j}{n}}{\binom{N}{n}} \right]$$

where S_n = number of species in a sample of n individuals, N = total number of individuals, N_i = number of individuals in species i, and N_j = number of individuals in species j.

Community similarity indices use occurrence of individual species along with their proportional abundances to compare the species richness of communities (ecological subsections). We chose the Morisita-Horn Index (Magurran 1988) to examine community similarity since it is less sensitive to individual species richness and sample size than many other similarity indices (Wolda 1983, Smith 1986). The disadvantage of this index is that it is sensitive to the abundance of the most abundant species in the sample (Magurran 1988).

We calculated the Morisita-Horn Index as follows:

$$C_{mH} = \frac{2 \sum \left(Na_i \, Nb_i \right)}{\left(da + db \right) Na \, Nb}$$

where Na and Nb = total number of individuals in site a and site b, respectively, Na_i and Nb_i= number of individuals in the i^{th} species in site a and site b, respectively, da = $\sum an_i^2/aN^2$, and db = $\sum bn_i^2/bN^2$.

Morisita-Horn Index values range between zero and 1, with zero indicating that the communities being compared have no species in common and a 1 indicating that the communities being compared have 100% of their species in common. Using this index one ecological subsection can be compared to another in terms of species shared between the 2 subsections.

Species Abundance Distributions

In order to explore species abundance distributions we calculated species evenness and dominance indices for each ecological subsection. Hurlbert's (1971) Index of evenness was used to calculate the probability that 2 randomly sampled individuals from an area represent 2 different species and is referred to as the probability of an interspecific encounter (PIE). This index is interpreted as a probability and it is relatively unbiased by sample size and species richness (Magurran 1988, Gotelli and Entsminger 2003).

We calculated Hurlbert's Index as follows:

$$\mathrm{PIE} = \left(\frac{N}{N-1}\right)\left(1 - \sum p_i^{\,2}\right)$$

where N = total number of species in the sample and p_i = the proportion of the whole sample represented by species i.

Species evenness was also examined by determining what percentage of all individuals detected was required to identify 50% and 95% of the species we detected in each subsection.

The Berger and Parker Index (May 1975, Magurran 1989) measures dominance by dividing the number of individuals detected for the most common species by the total number of all individuals detected. This index is sensitive to sample size and insensitive to the presence of rare species. Both measures of evenness or dominance discussed above produce results that are constrained between zero and 1, with higher values indicating either greater evenness or dominance in species composition.

Diversity Indices

We chose the Shannon Index (Shannon and Weaver 1949, James and Rathbun 1981, Magurran 1988) to calculate avian species diversity by ecological subsection. We calculated Shannon's Index (H´), using natural logarithms, by the following formula:

$$H' = -\sum (p_i)(\ln p_i)$$

where p_i = proportion of individuals (from the total sample) of species i.

The variance around each H´ was calculated using:

$$S^2{}_{H'} = \left[\frac{\sum f_i \ln^2 f_i - \left(\frac{\left(\sum f_i \ln f_i\right)^2}{n}\right)}{n^2}\right]$$

where n = sample size and f_i = number of observations of species i.

We then tested the null hypothesis that the diversity of pairings of ecological subsections were equal using a 2-tailed t-test (α = 0.05; Magurran 1988, Zar 1999).

RESULTS

Species Richness

Site and Point Diversity

Pooling all data from all ecological subsections over the 2 years of the study resulted in a Preserve-wide site diversity of 85 species (Table 27) and a Preserve-wide point diversity of 5.2 ± 0.1 SE species/point (Table 27). The total number of species detected per subsection increased as the total number of bird detections increased (ANOVA; F = 5.310, df = 13, P = 0.0397). Site diversity at the ecological subsection level ranged from 9 to 53 species; 9 species were detected in the Snowy Domes unit but only 5 points were sampled in this small subsection (Table 27). The Yukon River Valley ecological subsection had the highest site diversity with 53 species; this diverse subsection is composed of 6 detailed ecological units, several of which yielded 25-34 species each. Other detailed ecological subsections with relatively high site diversity included the Ogilvie Foothills hill unit (OF1; 35 species) and the gentle vegetated ridges unit of the Upper Charley Mountain Tundra subsection (MT3; 34 species; Table 27). The total number of species detected decreased with increasing elevation (ANOVA; F = 56.856, df=33, P < 0.000).

Overall, point diversity ranged from 3.3 ± 0.2 SE to 7.1 ± 0.3 SE species/point within ecological subsections and from 2.0 ± 0.4 SE to 7.2 ± 0.4 SE species/point for detailed ecological units (Table 27). The number of species per point by subsection increased as the number of birds detected per point increased (ANOVA; F = 82.086, df = 13, P < 0.000).

Rarefaction

The expected number of species and variances for the 13 ecological subsections were calculated at 2 levels;100 and 200 detections [$E(S_{100})$ and $E(S_{200})$; Table 28]. The number of species expected for samples of 100 [$E(S_{100})$] and 200 [$E(S_{200})$] individuals ranged from 15.1 to 32 for the 13 subsections investigated (Table 28). The Yukon River Valley ecological subsection had the greatest number of species per number of individuals detected (Table 28) and therefore produced the highest of the 13 curves (Figure 9). The Ogilvie Foothills and Tintina Hills ecological subsections also had high curves at the 200 species level. Ecological subsections with the lowest curves (reflecting the lowest number of species expected per number of individuals sampled) were Thanksgiving Loess Plain, Biederman Hills and Hardluck Lowland (Figure 9).

Community Similarity

We calculated the Morisita-Horn Index to examine the species similarity between ecological subsections. The calculated index values ranged between 0.10 and 0.92 (Table 29). Species composition was most similar between the Three Fingers Subalpine Basin and Upper Charley Mountain Tundra ecological subsection (0.92; Table 29). Other ecological subsection pairings with high species composition similarity were Charley Foothills and Ogilvie Lime/dolostone Mountains; Ogilvie Foothills and Ogilvie Lime/dolostone Mountains; Charley Foothills and Ogilvie Foothills; and Kandik Tableland

and Tintina Hills (Table 29). The subsection pairing that contained the fewest species in common was Upper Charley Mountain Tundra and Biederman Hills (0.10; Table 29).

Species Abundance Distributions

Species evenness was high for all subsections (Hurlbert's Index; range 0.842 – 0.932; Table 30), with species in the Yukon River Valley, Charley Foothills and Three Fingers Subalpine Basin ecological subsections exhibiting the greatest evenness of species distribution. Low numbers of detections were required in these subsections to identify 50% and 95% of the species in these units (Table 31). Species in Biederman Hills, Kandik Tablelands, and Thanksgiving Loess were least evenly distributed (Table 31) and relatively high numbers of detections were required to identify 50% and 95% of the species in these units.

Similarly, the Berger and Parker Index produced dominance values between 0.137 and 0.325 (Table 30), with Biederman Hills, Kandik Tablelands, and Thanksgiving Loess ecological subsections displaying the greatest dominance of species and the Charley Foothills, Yukon River Valley and Upper Charley Valleys subsections exhibiting the least dominance of species abundance (Table 30).

Diversity Indices

Shannon Index values (H´) for ecological subsections ranged from 2.258 to 3.067, with the Yukon River Valley subsection being most diverse followed by Three Fingers Subalpine Basin and Tintina Hills (Table 30). The Biederman Hills ecological subsection was least diverse and received the lowest H´ index value. Variances around Shannon Index values were small (Table 30). Seventy-three percent of all ecological subsection pair combinations were significantly different from each other (Table 32). The Yukon River Valley ecological subsection (the subsection with the highest H´ value) was significantly different from all other units in terms of species diversity (Table 32). Species diversity for the Biederman Hills subsection (which had the lowest H´ value) was significantly different from all other subsections except Thanksgiving Loess Plain.

DISCUSSION

Species Richness

Species richness measures are commonly reported in the literature as the total number of species detected in a study area or as the mean number of species detected per unit of standardization. These estimators assume that all species have equal probabilities of detection, irrespective of whether they are common or rare (Peet 1974). As we determined in Chapter 2 (this report), all species do not have equal probabilities of detection. This assumption of equal probability of detection is not often addressed in the published literature (but see Boulinier et al. 1998) and may have a significant effect on species diversity calculations.

Species richness values are not directly comparable to any areas other than themselves when re-surveyed. The metric of site diversity in particular has very limited use when comparing sites between studies, since the area of each site and the number of point count locations within them vary and are often not reported in the literature. Comparison of species richness between sites is also difficult because site classifications vary between study areas. For instance, spruce-dominated ecological subsections in the Preserve had site diversity values ranging from 19 (Thanksgiving Loess Plain) to 35 species (Upper Charley Valleys; Table 27), while site diversity was 39 species for a small sample of routes in spruce-dominated forests in Denali National Park (Paton and Pogson 1996). Spruce-dominated forests in the Preserve could either be considered to have much lower site diversity or nearly the same, depending on which ecological units were being used for the comparison.

Further difficulty in comparing species richness between samples is due to differences in the number of species detected based on 1) the size of the areas sampled (the species-area relationship) and 2) the total number of birds detected (the sample size-richness relationship; Connor and McCoy 1979, Maguran 1988). The species-area relationship states that the larger the area surveyed, the greater the number of species that will be detected. This precludes directly comparing species richness between areas of different sizes. We found much evidence for this relationship in our site level data. The 6 ecological subsections with the greatest number of points surveyed (points were proportionally allocated based on ecological unit size) were also the ecological subsections with the highest site diversity values (Table 27). Also, the Snowy Domes subsection contained the least number of points and, as expected by the species-area relationship, was found to contain the fewest number of species. However, there was not a one to one correlation between the ranks of the number of points surveyed per ecological subsection (indicative of area) and their corresponding ranks for the number of species detected.

The sample size-richness relationship states that samples with more individuals detected usually contain more species (i.e. have higher site diversity). This relationship is not linear, so proportionally reducing the number of species in samples of different sizes in order to compare the samples is not statistically valid (Preston 1960). With the exception of the Three Fingers Subalpine Basin, the ecological subsections with the greatest number of individuals also contained the greatest number of species detected (Table 27). This relationship did not hold for the Three Fingers Subalpine Basin, which had the greatest number of individuals detected overall but ranked seventh in the number of species detected. We also did not find a one-to-one correlation between the ranks of the number of points surveyed and the number of species detected.

Problems in assessing species richness due to the species-area and sample size-richness relationships can be minimized by using species per point as a measure, thereby standardizing both sample area and effort. The species-area relationship did not affect subsection species richness when using species/point measures. For instance, we found the Upper Charley Mountain Tundra ecological subsection (which contained the greatest number of points and hence, greatest area) had one of the lowest species/point values (Table 27). Even the Snowy Domes subsection which contains by far the fewest number of points (therefore the smallest area examined) did not have the lowest number of species per point. Species richness in several other ecological subsections do not follow the generally accepted species-area relationship when using species/point to measure species richness (Table 27).

Site Diversity

Site diversity values allow us to make rough comparisons of species richness between ecological subsections and detailed ecological units in the Preserve and will provide a general measure for tracking changes in the number of species in these units over time. Calculation of site diversity was made at 3 different scales; Preserve-wide, ecological subsection, and detailed ecological unit (Table 27). Site diversity for the Preserve was 85 species. This measure is comparable to a site diversity measure of 80 species in Denali National Park that was obtained when road-side routes in various habitat types were pooled (Paton and Pogson 1996).

On the subsection level, the Yukon River Valley subsection had the highest site diversity in the Preserve (Table 27). This subsection is divided into 6 detailed ecological units and is therefore also the most ecologically diverse unit, providing habitat for a broad variety of bird species (Table 8). The presence of lake, stream, and seasonal water bodies in the Yukon River Valley subsection provided habitat for waterbird species that were absent from most of the other subsections. A high number of species was also detected in the Upper Charley Mountain Tundra subsection, which is composed of 3 detailed ecological subsections. Several species were unique to this alpine tundra unit: Golden Eagle, American Golden Plover, Surfbird, Short-eared Owl, Say's Phoebe, Northern Wheatear, Snow Bunting, and Rosy Finch. With the exception of the Ogilvie Foothills, the other subsections with high numbers of species (Upper Charley Valleys, Tintina Hills, and Charley Foothills) were not divided into detailed ecological units. Occurrence of wildland fires in the Ogilvie Foothills, Tintina Hills, and Charley Foothills has likely created a mosaic of habitats in those units that support a variety of bird species.

On the detailed ecological scale, the Upper Charley Valleys (UC2), Ogilvie Foothills (OF1), Wet Terraces with Few Ponds (YV3), High Terraces, Undulating (YV5), and Gentle Vegetated Ridges (MT3) units had the highest site diversity values (Table 27). These units often transitioned between prominent vegetation zones (such as treeline), had diverse topography, or contained diverse water habitats. The resultant habitat diversity supports a variety of bird species.

Point Diversity

Point diversity values are standardized by calculating the number of species per point averaged over all the points in the unit. These standardized measures facilitate making comparisons of species richness between units. The ecological subsection with the greatest point diversity is the Three Fingers Subalpine Basin (7.1 species/point; Table 27). Other subsections with high point diversity include the Yukon River Valley, Charley Foothills, Upper Charley Valleys, and Oglivie Foothills. These areas are either transitional units spanning forested to alpine tundra communities or have a history of wildfire or flood disturbances that have produced a variety of habitat types for birds. Vegetation in the Three Fingers Subalpine Basin (elevation 914-1280 m) is comprised of sedges and low shrubs in valley bottoms, shrubs with spruce woodland on slopes, and herbaceous vegetation or dwarf shrubs on hilltops (D. Swanson 1999). This gradation of vegetation communities provides diverse habitats capable of supporting a wide variety of avian species. A study of bird populations in the Kluane Mountains in Canada also found high numbers of species in subalpine areas (Theberge 1976).

The ecological subsection designated least diverse using point diversity is the Thanksgiving Loess Plain. This subsection has wet soils underlain by permafrost and a relatively low incidence of wildfire, resulting in large tracts of uniform open Black Spruce and Bog Birch vegetation which does not support a diverse group of avian species. Similarly, Hobson and Bayne (2000) found that monospecific single-aged stands contained fewer avian species than mixed wood stands. The Upper Charley Mountain Tundra ecological subsection also had low point diversity, despite the fact that this unit is the largest of the subsections (24%) and had the most points surveyed (Table 27). Vegetation in the unit consists primarily of shrubs with some tussock tundra at lower elevations and is sparsely vegetated with considerable rock exposed at higher elevations (D. Swanson 1999). Vegetation height in this unit is uniformly low, a situation correlated with low avian diversity (MacArthur 1965, Kessel 1998). Additionally, the Upper Charley Mountain Tundra subsection encompasses the highest elevations in the Preserve, and, as in this study, species richness has been found to decrease with increasing elevation (Pianka 1966, Tramer 1974).

Point diversity values for detailed ecological units were more varied than for ecological subsections and ranged from 2.2 to 7.2 species/point (Table 27). The Nation/Kandik/Bonanza Valleys (YV6) had the highest point diversity among the detailed ecological units. This detailed ecological unit is vegetatively diverse, containing floodplain shrubs and Balsam Poplar/White Spruce forests in the riparian zone and tussock wetland or Black Spruce woodland on wet terraces and footslopes (D. Swanson 1999). The variety of habitats available in this community would support a diverse group of avian species. The Subalpine Valleys (UC1) and Beverly/Copper/East Fork Mountain Slopes (UC2) detailed ecological units also had high point diversity values and habitat diversity is likely a primary factor in determining this high avian diversity. Habitats in these high elevation units encompassed sedge; dwarf, low, and tall shrub; and spruce woodland habitats (D. Swanson 1999). Trees in these units (and in Three Fingers Subalpine Basin) serve as stringers of woodland habitat in an otherwise tundra landscape.

Rarefaction

Based on the expected number of species calculated from rarefaction curves (Fig. 9 and Table 28), species richness per number of individuals detected is highest in the Yukon River Valley subsection and lowest in the Thanksgiving Loess Plain. Subsection rankings for species richness based on rarefaction curves change little between the $E(S_{100})$ and $E(S_{200})$ levels (Table 28). With the exception of the Ogilvie Lime/dolostone Mountains subsection, these rankings also are in agreement with those for the actual number of species detected (site diversity; Table 27). The Ogilvie Lime/dolostone Mountains subsection was ranked seventh at the $E(S_{200})$ level and twelfth by the total number of species detected. This subsection had the fewest number of sample points and would be expected to have fewer species detections than predicted by rarefaction, which accounts for biases in numbers of samples and differences in numbers of individuals sampled.

Community Similarity

When comparing the number and proportional abundance of species between ecological subsections, we found that Three Fingers Subalpine Basin and Upper Charley Valleys had the most avian species in common (Table 29). Both of these relatively high elevation river valley subsections transition between woodland habitat and shrub-dominated communities and therefore offer similar habitat opportunities to avian species. Twenty-four of the 28 bird species detected in the Three Fingers Subalpine Basin were also found in the Upper Charley Valleys ecological subsection and many of the common species had proportionally similar species abundances. For instance, White-crowned Sparrow was the species detected most often in both ecological subsections and represented 15% of all individuals detected in the Upper Charley Valleys and 17% in the Three Fingers Subalpine Basin. Additionally, several species detected only infrequently during the inventory (i.e., Northern Harrier, Three-toed Woodpecker, and Spotted Sandpiper) were found in these 2 ecological subsections, further indicating that they had similar species compositions.

The Ogilvie Lime/dolostone Mountains, Ogilvie Foothills, and Charley Foothills also had a high number of species in common (Table 29). The 4 most frequently detected species in these 3 subsections were Dark-eyed Juncos, Yellow-rumped Warblers, Varied Thrush and Swainson's Thrush. The proportions of all individuals detected for each of these species were highly comparable between subsections. The Ogilvie Foothills grade into the Ogilvie Lime/dolostone Mountains and both units have steep topography with rocky outcrop exposures, thus providing similar habitat options for bird species. The Charley Foothills is in the Dawson Mountain range, but is at the same elevation as the Ogilvie Foothills and shares similar fire histories. Additionally, Charley Foothills and Ogilvie Foothills both contain large tracts of late-successional (spruce-dominated) vegetation (D. Swanson 1999). These physical and vegetation similarities likely result in similar bird communities between these subsections.

In contrast, the Biederman Hills and Upper Charley Mountain Tundra ecological subsections had the least number of species in common (Table 29). The total numbers of species detected differed greatly between the Biederman Hills (24 species) and Upper Charley Mountain Tundra (38 species) subsections. Of the 24 species detected in the Biederman Hills, 17 were also found in the Upper Charley Mountain Tundra subsection, but the proportional abundance of many of these shared species varied greatly between the two units.

Species Abundance Distributions

The ecological subsections with the most even species abundance distributions were the Yukon River Valley, Charley Foothills, and Three Fingers Subalpine Basin units (Table 30). In all three subsections, a small number of detections resulted in a relatively high percentage of the species being identified, indicating high evenness of species abundance distributions. Species dominance was also low in these units (Berger and Parker Index; Table 30). In the Yukon River Valley subsection, 8% of all individuals detected were needed to detect 50% of the species in this unit and 79% were needed to detect 95% of the species (Table 31). Only 36% of all individuals detected in this subsection were contained in the unit's top three, numerically dominant species [Swainson's Thrush (15% of the individuals detected), Dark-eyed Junco (13%), and

White-winged Crossbill (8%)]. This suggests high evenness of species abundance distribution and low dominance of species. The Yukon River Valley subsection had the highest Hurlbert's Index value and the second lowest Berger and Parker Index value among the ecological subsections, statistically demonstrating high evenness and low dominance of species (Table 30).

With only 3% of all individuals detected in the Charley Foothills subsection, 50% of all species had been detected and with only 66% of all individuals detected, 95% of all species had been detected. Only 38% of all individuals detected in this subsection were contained in the unit's top three, numerically dominant species [Dark-eyed Junco (14% of the individuals detected), Yellow-rumped Warbler (12%), and Varied Thrush (12%)]. The Charley Foothills ecological subsection had the 2nd highest Hulbert's Index value, and the lowest Berger and Parker Index value (Table 30).

Many individuals but relatively few species were detected in the Three Fingers Subalpine Basin subsection (Table 27). Identifying 50% and 95% of the species detected in the Three Fingers Subalpine Basin unit required 7% and 72% (respectively) of all individuals detected (Table 31). Individual species dominance in this unit showed slightly less evenness of species abundance distribution than the Charley Foothills unit. Forty-three percent of all individuals detected in this subsection were contained in the unit's top three numerically dominant species [White-crowned Sparrow (17% of the individuals detected), American Tree Sparrow (14%), and Yellow-rumped Warbler (8%)]. The Three Fingers Subalpine Basin ecological subsection had the 3rd highest Hulbert's Index value, and the 4th lowest Berger and Parker Index value (Table 30).

The 3 ecological subsections with the most uneven distribution of species abundance were Biederman Hills, Kandik Tablelands, and Thanksgiving Loess Plain. These units had low Hurlbert's Index values and high Berger and Parker Index values (Table 30). The Biederman Hills subsection received the lowest evenness value and highest dominance value of any of the units in the Preserve (Table 30). This unit required 11% of all individuals detected to identify 50% of all species and 83% of all individuals to detect 95% of all species (Table 31). Collectively, the top three species detected in this subsection accounted for 56% of the individuals detected. White-winged Crossbill accounted for 32% of all individuals detected (the greatest percentage of any one species in an ecological subsection found in this study), Swainson's Thrush accounted for 14% and Yellow-rumped Warbler accounted for 10%.

The Kandik Tablelands received the second lowest evenness and second highest dominance value after the Biederman Hills unit (Table 30). The Kandik Tablelands required the highest percentage of individuals (11%) to detected 50% of all species and the 2nd highest percentage of individuals (94%) to detect 95% of all species (Table 31). These values depict a unit with very low evenness of species abundance distribution and high dominance of species. Dark-eyed Junco comprised 29% of all individuals detected with Swainson's Thrush and Orange-crowned Warbler comprising 18 and 10%, respectively. Together, these 3 numerically dominant species contained 57% of all individuals detected in this unit, the greatest percentage calculated for any unit in this study.

The Thanksgiving Loess Plain received the third lowest evenness and third highest dominance value of all ecological subsections in the Preserve (Table 30). White-winged Crossbills comprised 26% of all individuals detected in this unit with Dark-eyed Junco and Varied Thrush comprising 18% and 9%, respectively. Together, these 3 numerically dominant species contained 53% of all individuals detected in this unit, the 3rd greatest percentage calculated for any unit in this study.

Diversity Indices

The Shannon Index values for ecological subsections in this study ranged from 2.258 to 3.067 and ranks of these values closely parallel the corresponding ranks for Hurlbert's Index values (Table 30). Both indices are based on proportional abundance of species and should produce similar results. By way of comparison, reported values for the Shannon Index usually fall between 1.5 and 3.5 and are only rarely greater than 4.5 (Magurran 1988). Variances around the Shannon Index values ranged from 0.0004 for the Charley Foothills and Upper Charley Mountain Tundra units to 0.0220 for the Snowy Domes unit (Table 30) and were reflective of the total number of individuals detected in each unit (Table 27).

By comparing subsection species diversities (H´), we hoped to distinguish which ecological units were most similar (Table 32). Results of these comparisons did not correspond with information obtained from the community similarity index, though both indices account for species number and abundance. Ecological unit pairs that should have been similar based on community similarity index values were significantly dissimilar and vice versus. For instance, the community similarity index value for Ogilvie Mountains and Ogilvie Foothills was 0.91, indicating that both subsections contain similar species and abundances of these species (Table 29). However, results of the t-test comparing species diversity (H´) between the 2 subsections indicated that they were not similar in terms of species diversity. The opposite of this was found with the Upper Charley Mountain Tundra and Kandik Tableland comparison, where t-test results indicated a highly similar species diversity between the two (P = 0.000; Table 32) but the community similarity value signified very few common species and species distributions.

Spindler and Kessel (1980) found that breeding species diversity (measured by a Shannon Index value of 1.90) was highly correlated with the number of species detected ($r^2 = 0.61$, $n = 23$, $P < 0.001$) and so chose to use site diversity (the number of species detected) as their measure of diversity. We also found a high correlation (at the ecological subsection level) between Shannon Index values and the number of species ($r^2 = 0.65$, $n = 13$, $P < 0.001$). Our results tend to support Spindler and Kessel's (1980) and Wolda's (1983) assertions that simple counts of species richness may be as good a measure of avian diversity as more complex diversity indices. However, we advocate using community similarity and proportional abundance distribution measures to gain a more complete understanding of the avian communities being studied.

CONCLUSIONS

Analysis of bird inventory data from Yukon-Charley Rivers National Preserve has provided measures of species richness at Preserve-wide, ecological subsection, and detailed ecological unit scales. These measures of species richness are the first to be compiled for the Preserve and will serve as baseline data for comparisons with future inventory and monitoring efforts. These data will be instrumental in developing a robust bird monitoring program for the Preserve that can ascertain changes in bird species composition and numbers of individuals over time. Species diversity information gained from this study also will be essential for developing land management guidelines for the Preserve.

The indices we chose to use in this chapter have added greatly to our knowledge of bird species distribution in the Preserve. Through species richness and community similarity calculations, we are now able to identify which ecological subsections and detailed ecological units in the Preserve are likely to have unique bird species or assemblages. This type of information will allow researchers to more efficiently locate and monitor avian species or communities of interest or concern.

We used rarefaction to standardize our species richness data and the resultant values can now be used to compare species richness between different areas of the Preserve and also outside of the Preserve boundaries. We can also use rarefaction calculations to determine the sampling effort required in each ecological subsections to maximize the number of species detected and minimize sampling intensity. For instance, based on rarefaction calculations, increasing sampling effort in the Yukon River Valley subsection would result in more new species than in the Thanksgiving Loess subsection. This procedure can also point out situations where the sampling intensity required would be greater than the level of funding or personnel available.

Community similarity indices provided insight into differences in avian assemblages between ecological subsections in the Preserve. This knowledge of areas with high and low similarity will assist us in designing sampling schemes for future avian studies in the Preserve.

We were able to assess how uniformly distributed the species within ecological subsections were using evenness and dominance indices. This information is useful to further assess similarity between ecological subsections. Though these indices measured how even or uneven (dominance) the abundances are for species in an ecological subsection, they provide no information on which species or group of species makes up the dominant component of the area being studied.

Many diversity indices incorporating proportional abundance of species (combining species richness and evenness) have been developed and these are widely reported in the ecological literature. However, there is great debate over how diversity should be measured and what those measurements tell us about the community being studied. It is imperative to keep in mind that no pattern of diversity is without variations and exceptions and that the method chosen to calculate diversity will have a profound effect on the outcome of the calculation and thus on the conclusions drawn.

In spite of minor differences in patterns of species diversity from the different diversity measures discussed above, we found the Yukon River Valley and the Three Fingers Subalpine Basin subsections to be the most “diverse” units in Yukon-Charley Rivers National Preserve. The spatially heterogeneous floodplain and terrace environment of the Yukon River Valley subsection supports a complex mosaic of vegetation types that provide suitable habitat for a large variety of bird species. Wildfire disturbance in this unit is patchy. The Three Fingers Subalpine Basin subsection contains an ecotonal mix of forest and tundra microenvironments which also support a high diversity of bird species. In other moderately diverse ecological subsections (e.g. Charley Foothills and Tintina Hills), wildfires appear to be important in maintaining habitat diversity and, hence, avian species diversity.

The Thanksgiving Loess Plain subsection is the least “diverse” unit in the Preserve. This subsection (and others with low diversity such as the Hard Luck Lowland and Biederman Hills) has wet soils underlain by permafrost and large tracts of uniform open Black Spruce and Bog Birch vegetation. This type of vegetation does not support a diverse group of avian species.

Results of Shannon Index calculations show that almost ¾ of all ecological subsection pairings were significantly different from each other, indicating that there are widespread differences in numbers of species present and proportional abundance of these species within ecological subsections in the Preserve.

RECOMMENDATIONS

As found by other authors our data shows a high level of correlation between point diversity and Shannon diversity index values. Several authors have advocated this correlation as a reason to use species richness as their sole measure of diversity. However, our explorations of other measures of diversity suggest that there is additional information to be gained by calculating more than simply point diversity. Although we have found patterns in our data to help determine differences in the distribution of species abundance between ecological subsections we feel no single index or pattern of numerical dominance can completely explain or interpret the differences in species composition and abundance in any community. Therefore, many different approaches should be utilized to gain the most completely understanding of avian species composition and abundance for a given area.

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